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Updated estimates of exploitation from tagging of Atlantic *cod (Gadus morhua)* in NAFO Subdiv. 3Ps during 1997-2003.

Mise à jour des estimations des taux d'exploitation de la morue Atlantique (*Gadus morhua*) dans la sous-division 3Ps de l'OPANO de 1997 à 2003 d'après les résultats d'une expérience d'étiquetage.

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ABSTRACT

This document updates the results of a multi-year tagging study of Atlantic cod (*Gadus morhua*), initiated in NAFO Subdiv. 3Ps in spring 1997, with about 8,000 additional cod tagged and released during April-June 2003. Since inception, a total of over 60,000 cod have been tagged with single, double, or high-reward t-bar anchor tags and released at various inshore and offshore sites off southern Newfoundland (3Ps) and 9,993 (16.5%) have been reported as recaptured to 30 September 2003. Estimates of exploitation for cod tagged in each region were computed using methods similar to those reported in our previous documents, but with minor modifications. Estimates of short-term tagging mortality, tag loss, and reporting rate were also obtained and are incorporated. Among cod tagged in Placentia Bay mean annual estimates of exploitation have declined from 33% in 1999 to 20% in 2002; however, some individual estimates remain quite high with six of 14 estimates exceeding 20% in 2002. Mean annual estimates for cod tagged in Fortune Bay have been fairly stable at 10% to 11%; however, cod tagged at Poole's Cove are being more heavily exploited than those off Pass Island in the outer reaches of Fortune Bay. Mean annual estimates for cod tagged in offshore areas remain consistently low (4% to 9% among cod tagged in 3Psd; 1-3% among those tagged in 3Psh). Some of the cod tagged in 3Psd (Burgeo Bank) are exploited in the neighbouring 3Pn4RS stock area, suggesting that stock mixing may extend to April in some years. As reported in previous analyses the exploitation estimates for 3Psh are extremely low given annual reported offshore landings ranging from 4,000 - 12,000 t during 1998-2002. Possible reasons include limited offshore tagging coverage, restricted distribution of offshore fishing effort, and low survival of cod offshore for tagging in deep (> 200m) water. In particular, there are substantial landings from areas on St. Pierre Bank (3Pse, 3Psf) that have generated few tag returns, suggesting that there are offshore stock components that have not been tagged. More extensive tagging coverage of the St. Pierre Bank area, particularly during fall, could improve the reliability of the exploitation estimates for the offshore regions.

RÉSUMÉ

Nous présentons une mise à jour des résultats de l'expérience d'étiquetage pluriannuelle de la morue Atlantique (*Gadus morhua*) entreprise au printemps 1997 dans la sous-division 3Ps de l'OPANO, reposant sur quelque 8 000 autres morues étiquetées et remises à l'eau d'avril à juin 2003. Depuis le début de cette expérience, un total de plus de 60 000 morues ont été munies d'une marque à ancrage en T à récompenses simple, double ou élevée, puis remises à l'eau à divers points de la côte et de la haute mer dans la sous-division 3Ps de l'OPANO, située au sud de Terre-Neuve. Au 30 septembre 2003, 9 993 (16,5 %) de ces morues avaient été recapturées. Nous avons légèrement modifié les méthodes que nous avons utilisées dans nos études précédentes pour estimer les taux d'exploitation des morues étiquetées dans chaque secteur. Nous avons aussi fait des estimations du taux de mortalité à court terme due à l'étiquetage, du taux de perte d'étiquettes et du taux de déclaration des étiquettes récupérées. Dans le cas de la morue étiquetée dans la baie de Plaisance, les taux d'exploitation annuels moyens estimés ont diminué, passant de 33 % en 1999 à 20 % en 2002; certains demeurent toutefois assez élevés, 6 de 14 estimations dépassant 20 % en 2002. Variant entre 10 et 11 %, les taux pour la morue étiquetée dans la baie de Fortune sont demeurés relativement stables; par contre, la morue étiquetée dans l'anse Poole's est plus fortement exploitée que celle retrouvée au large de l'île Pass, située à l'entrée de la baie de Fortune. Les taux pour la morue étiquetée dans les eaux hauturières demeurent faibles sans exception (4 à 9 % pour la morue étiquetée dans 3Psd; 1-3 % pour celle étiquetée dans 3Psh). Un certain nombre de morues étiquetées dans 3Psd (banc Burgeo) sont capturées dans les eaux voisines de 3Pn4RS, ce qui donne à penser que les stocks se mélangent jusqu'en avril certaines années. Comme nous l'avons indiqué dans les analyses précédentes, les taux d'exploitation estimatifs pour 3Psh sont extrêmement faibles même si les débarquements annuels signalés de prises hauturières se situaient entre 4 000 et 12 000 t de 1998 à 2002. Cela pourrait être dû à une couverture d'étiquetage limitée des eaux hauturières, une distribution restreinte de l'effort de pêche hauturière et à un faible taux de survie de la morue étiquetée en haute mer (> 200 m). En particulier, les fortes prises récoltées dans certains secteurs du banc de Saint-Pierre (3Pse, 3Psf) ne contenaient que peu de morues étiquetées, ce qui donne à penser que des composantes hauturières du stock n'ont pas été étiquetées. Une couverture d'étiquetage plus vaste du banc de Saint-Pierre, en particulier durant l'automne, permettrait d'améliorer la fiabilité des estimations des taux d'exploitation dans les eaux hauturières.

Introduction

A mark-recapture study of Atlantic cod (*Gadus morhua*), initiated in NAFO Subdiv. 3Ps during 1997, was continued during 2002-2003. The purpose of the study was to provide information on movement patterns of 3Ps cod with as well as obtain estimates of exploitation rates on different components of the stock.

Annual estimates of exploitation are given for each tagging experiment conducted in 3Ps during 1997-2002 using the methods described in Brattey et al. (2003) with some minor modifications. This document also gives a summary of the spatial and temporal distribution of recaptures of tagged cod released in various regions of Subdiv. 3Ps during April 1997-June 2003 and reported as recaptured up to the end of September 2003. Previous results from post-moratorium cod tagging studies in 3Ps and adjacent areas are reported in Lawson et al. (1998), Brattey (1999, 2000), Brattey et al. (1999, 2002a), Robichaud and Rose (2001, 2002). Historical cod tagging studies (prior to 1994) in the Newfoundland Region are summarized in Taggart et al. (1995), Myers et al. (1996, 1997). Further analyses of the data from the post-moratorium cod tagging experiments are presented elsewhere (Brattey and Cadigan, in press; Cadigan and Brattey 1999a, b; 2000a, b; 2001, 2002, 2003; Lawson and Rose 2000; Lilly et al. 2001; Pope and Brattey 2001). Methods to estimate tagging mortality, and tag loss and reporting rates from the data reported herein are described in Brattey and Cadigan (in press) and Cadigan and Brattey 2003.

Materials and Methods

Cod for tagging were captured with various gears (mostly hand-line and otter-trawl), measured (nearest cm) and tagged with one or two t-bar anchor tags inserted at the base of the first dorsal fin, and released. Experienced technicians conducted the tagging. Only cod ≥45 cm (fork length) that appeared healthy were tagged and each batch of cod typically consisted of individuals tagged with either single, double, or high–reward tags. The tags were uniquely numbered and bore a return address as well as the value of the reward ($10 for one single, $20 for two singles, or $100 for high-reward). The tagging program was advertised extensively among those participating in the fishery. Details of the tagging experiments are summarised in Table 1. The number of cod tagged annually ranged from about 6,000 to 10,000. The sizes of tagged cod ranged from 45 to about 115 cm with mean lengths mostly in the 55-65 cm range. Approximately 56 tagging experiments have been conducted at various sites in 3Ps; most tagging has been conducted on spawning and pre-spawning aggregations at the head of Placentia Bay (3Psc), the head of Fortune Bay (3Psb), off Pass Island in the outer reaches of Fortune Bay, in the Burgeo Bank area(3Psa/d), in the Halibut Channel area (3Psh), and on one occasion off the north-western corner of St. Pierre Bank (3Psd)(Fig. 1).

Reported landings of cod from 3Ps (up to September 2003) and from neighbouring stock areas (3Pn4RS and 3KL) during recent years were extracted from the Statistics Branch catch database and are summarized to aid in the interpretation of tag returns.

Estimation of exploitation rates

Development of the methods used to estimate exploitation rates is ongoing and the methods used here are similar to those described in Brattey and Healey (2003). Data from tag release and recaptures in 3Ps in 1997-2003 were used herein. As in previous analyses (Brattey and Healey 2003; Brattey et al. 2002a), we did not attempt to estimate population sizes using tag returns and commercial catches in this analysis, because typically some harvesting occurs in an area different from where fish were tagged; this makes it difficult to convert local catches to local population biomass. Methods to estimate cod biomass from tagging data and catches are presented elsewhere (Lilly et al. 2001; Pope and Brattey 2001; Cadigan and Brattey 2001, 2002).

Tag-induced mortality (τ) was estimated from experimental studies (Brattey and Cadigan, in press). An overall estimate of 0.12 was obtained, indicating that on average 12% of tagged cod succumbed "immediately" after tagging (a preliminary overall estimate of 0.13 was used in our previous documents). More detailed analysis has shown a significant seasonal tagging mortality effect which appears to be related to water temperature. Brattey and Cadigan (in press) found that tagging mortality was low (0.03) during spring (April-May) and higher (0.22) during late summer and fall (August-November); therefore, seasonal estimates of tagging mortality (τ) were used in the current analysis based on the month of release. The estimate of 0.03 was used for release months 1-6 and 0.22 for release months 7-12.

Our method of estimating reporting rate (λ) is based on a high-reward tagging study, described in detail in Cadigan and Brattey (2003) and updated with recent recaptures. We used annual, region-specific estimates of reporting rate calculated from the high-reward tagging study; high-reward tags were assumed to have a reporting rate of 1.0.

Tag loss rates (ϕ) were estimated from a double-tagging study (see Cadigan and Brattey 2003), which showed that tag loss mostly occurred in the first 3-4 months after release with only minimal losses thereafter. We used the model proposed by Kirkwood (1981) to estimate tag loss rates

$$\phi_t = ((\beta_0/(\beta_0 + \beta_1 t))^{\beta 0}; \ \beta_0, \beta_1 \geq 0$$

where t is the time at liberty. Cadigan and Brattey (2003) show that this model is more suitable than the proportional tag loss model proposed by Barrowman and Myers (1996). For each recapture year, we computed a time at liberty, which in the first year corresponds to the number of weeks between the median date of release of tagged fish and the median recapture date of tagged individuals in the year of release. For subsequent years, time at liberty is calculated by incrementing the number of weeks between the annual median dates of recapture.

Our analyses has shown that the rate of loss of tags depends on position and that the front tag of a double tagged fish is lost at a faster rate than the back tag; thus, there are three types of recapture from a double tagged fish: (the front tag only, the back tag only, or both tags). The tag loss model was used to compute the proportion of initial number of tags applied that were retained at the median date of recapture for each recapture year. This was done separately for each type of tag return.

To estimate exploitation annually, we tracked the numbers of fish available for capture in each year, accounting for tag loss and assumed natural mortality. The instantaneous rate of natural mortality (m) assumed to be 0.2 per yr. The recaptures from each region (R) were adjusted by the reporting rate (R^*). In the initial year, we immediately removed those cod that die "instantly" due to tagging mortality. The estimates of loss are actually retention rates (ϕ) using Kirkwood's model and apportioned by the time at liberty. Natural mortality (m) was also apportioned by the time-at-liberty, i.e. $e^{-m(t/52)}$

Let $M(t)_{eff}$ denote the "effective" number of tagged fish available in year t prior to the fishery. After the fishery in year t, let $next_t$ denote the number of tagged fish remaining. For fish having a single tag, in the year of release, if T_0 is the number of fish tagged and released,

$$M(0)_{eff} = T_0(1-\tau)\phi_0 m_0,$$

and

$$next_0 = M(0)_{eff} - R^*_0.$$

In subsequent years,

$$M(t)_{eff} = next_{t-1}\delta_{L_t}\delta_{m_t}$$

where

$$\delta_{L_t} = \phi_t / \phi_{t-1} \text{ and } \delta_{m_t} = m_t / m_{t-1},$$

and

$$next_t = M(t)_{eff} - R^*_t$$

Note that δ_{Lt} and δ_{mt} are the proportion of additional tag loss and natural mortality to be removed from the available population. We use such ratios because the values of N and m are relative to the initial numbers of tagged cod.

For fish that are double-tagged and released, additional attention is required when adjusting the annual loss rates and computing the effective number of tagged fish remaining. For example, in any given year, a double-tagged fish may lose neither or both tags, or, could lose only the anterior or posterior tag. First, consider those fish that have retained both of the tags:

$$M(0)_{eff} = T_{D0}(1-\tau)\phi_{A_0}\phi_{B_0}m_0$$

where ϕ_{A_0} and ϕ_{B_0} represent the tag retention of the anterior and posterior tags, and T_{D0} is the number of double-tagged fish released. After the fishery in the initial year,

$$next_0 = M(0)_{eff} - R^*_0.$$

In subsequent years,

$$M(t)_{eff} = next_{t-1}\delta_{L_t}\delta_{m_t}$$

where

$$\delta_{l_t} = \phi_{A_t}\phi_{B_t} \Big/ \phi_{A_(t-1)}\phi_{B_(t-1)} \text{ and } \delta_{m_t} = m_t \Big/ m_{t-1},$$

so the loss adjustment is made for both tags. After the fishery, we again have

$$next_t = M(t)_{eff} - R^*_t.$$

Double-tagged fish that lose one of their tags create two additional types of return to track: those that have the anterior tag only, and those that have the posterior tag only. In the first year, such individuals can only come from the double-tagged fish. However, in subsequent years, individuals with only the anterior tag come from two sources: those that had both tags in the previous year or those with only the anterior tag (which was retained) in the previous year. Thus, the number of individuals available to the fishery with the anterior tag only can increase over time. The identical situation exists for the individuals retaining the posterior tag. The expressions below indicate how we track fish that have the anterior tag (only) in place. In the year of release,

$$M(0)_{eff} = T_{D0}(1-\tau)\phi_{A_0}(1-\phi_{B_0})m_0, \text{ and}$$

$$next_0 = M(0)_{eff} - R^*_0.$$

In subsequent years, (keeping in mind that individuals with the anterior tag come from two sources as described above),

$$M(t)_{eff} = next_{t-1}\delta_{L_{A_t}}\delta_{m_t} + next_{D(t-1)}\delta_{L_D_t}\delta_{m_t},$$

where

$$\delta_{L_{A_t}} = \phi_{A_t} \Big/ \phi_{A_(t-1)}, \quad \delta_{L_D_t} = \phi_{A_t} \Big/ \phi_{A_(t-1)} \left(1 - \phi_{B_t} \Big/ \phi_{B_(t-1)}\right) \text{ and } \delta_{m_t} = m_t \Big/ m_{t-1}.$$

Here, $next_{D(t-1)}$ refers to the numbers of fish with both tags remaining available, δ_{A_t} is the tag-loss adjustment for individuals having the anterior tag only in the previous year, and $\delta_{L_D_t}$ is the tag-loss adjustment for double tagged fish in the previous year which have lost the posterior tag since the previous years fishery. Again we have

$$next_t = M(t)_{eff} - R^*_t.$$

Similar expressions are used to account for the numbers of fish available having the posterior tag only.

The exploitation rate $\mu(t)$ in year t for each experiment is estimated by summing the adjusted number of recaptures across tag types and dividing by the summed numbers of each tag type available to the fishery, i.e.:

$$\mu(t) = \frac{\sum_k R^*_{t(k)}}{\sum_k M(t)_{eff(k)}}.$$

The subscript k represents available tag types at time t. $M_{eff(k)}$ is the number of type k tags available at the time of the fishery in each year. Note that the annual median time at liberty is common across tag types within an experiment. Tagging experiments were conducted in consecutive years in some locations; thus multiple annual estimates of exploitation are given for some locations. Note that in some years tagged fish were released during the fishery and the first estimate of exploitation for these releases accounts for only a portion of the total exploitation in that year.

We also computed mean annual estimates of exploitation for each of the unit areas where fish were tagged. We used recaptures from the year of estimation and two preceding years in calculating these means, which were weighted by the numbers of tagged cod released (i.e. annual means for 2002 were based on recaptures from 2002, 2001 and 2000.

Results

Spatial and temporal distribution of cod landings

Reported monthly landings by unit area for 2002 are summarized in Table 2A. There were substantial landings (>1,000 t) in all unit areas, except 3Psg (91.8) and 3Psd (358 t) which is closed to directed cod fishing from November 15 – April 15. Highest landings (33-51% of the entire TAC) have come from Placentia Bay (3Psc) (Fig. 2) and reported landings from Placentia Bay in 2002 were about 1,000 ton less than in 2001 but still accounted for 33% of the overall catch compared to 39% in 2001. In the offshore, landings have mostly been highest in 3Pse/f/h, which includes the southern Halibut Channel and the northeastern and southeastern portions of St. Pierre Bank. Overall, the spatial distribution of landings in 2002 has been similar to that of 2001, although landings from 3Pse during 2002 were about 1,000 t higher than in 2001 and those for 3Psc less by a corresponding amount. Note that the catch by unit area reported herein includes French catches and therefore differs from that reported in Table 3 in Brattey et al. (2003).

At the beginning of the management year (April and May) inshore landings were low and came mostly from by-catch fisheries. There were substantial landings in all inshore unit areas during June -September 2002, particularly in Placentia Bay with reported landings of over 1,475 t in July alone. Landings were low in October in 3Psb, but peaked in 3Psa in October (327 t) and in 3Psc again in November (987 t). In the offshore, landings tended to be highest in Halibut Channel (3Psh) in late fall (November-December) and winter (January-March). There were also substantial landings from St. Pierre Bank (3Pse/f) during July-October.

Preliminary landings for the 2003 calendar year (Table 2A) show trends similar to those seen in 2002 with some notable exceptions. In particular, landings from Fortune Bay (3Psb) and Placentia Bay (3Psc) during September 2003 (1,113 t and 1172 t, respectively) are substantially

higher than those for the same month in 2002 (287 t and 352 t). Also, there are substantial landings from 3Psf (931 t) during January-February 2003 that are not evident in 2002.

Reported cod landings from adjacent management regions from 1998-2002 are summarized by unit area in Table 2B (Divs. 3KL) and Table 3C (3Pn4RS). The TAC's in these adjacent management units have been smaller than those in 3Ps (typically 3,000-9,000 t), and landings per unit area have ranged from a few hundred tons to over 1,000 tons, with the highest landings in 3Pn, 4R and 3La, 3Lb. A moratorium on directed cod fishing in these adjacent areas was re-introduced during 2003.

Numbers of recaptures

A matrix of the numbers of tagged cod reported as recaptured annually (for all tag types combined) up to the end of September 2003 is given by tagging experiment in Table 3. As in previous years, there have been substantial numbers of recaptures from most inshore tagging experiments, particularly those conducted in Placentia Bay during spring. Offshore taggings (Halibut Channel, Hermitage Channel, Burgeo Bank, NW St. Pierre Bank) have tended to generate substantially fewer recaptures. Tags are still being returned from some experiments 6 years after release, although the numbers are quite low.

Exploitation estimates

Annual estimates of exploitation (expressed as % of available numbers harvested) for each tagging experiment are summarized and grouped by unit area of release in Table 4. Tagging has been conducted at many locations in some unit areas; consequently, there are multiple estimates of exploitation for some areas, notably Placentia Bay (3Psc). Note that the values for preceding years may differ slightly from those reported in Brattey et al (2002a); this reflects slight change in the method of estimating reporting rate (see Table 6) and tag loss rate (see Brattey and Healey 2003), recovery of additional tags from previous years, and use of seasonal values for initial tagging mortality. Values for 2003 for all experiments are preliminary as the fishery was still in progress.

The number of cod tagged has been too low in the western portion of the inshore (i.e. 3Psa) to draw firm conclusions about exploitation of cod tagged in that region. Among cod tagged in two regions in Fortune Bay, estimates have tended to be low for cod tagged at Pass Island (4.6 - 10.7%) compared to those tagged at Poole's Cove (8.7 - 27.7%). Overall, the results indicate quite high exploitation of cod in the Poole's Cove area with 3 of 6 estimates for 2002 exceeding 22.0%. The overall annual means for 3Psb as a whole have been similar over the past three years at 10-11%.

Among cod tagged in Placentia Bay, estimates of exploitation for 2002 have been variable and generally higher for more recently tagged cod (1998 onwards). Highest estimates (typically 25-45%) are seen during 1999 and 2000 when both the overall TAC and landings in Placentia Bay were highest (see Fig. 2). Estimates of exploitation in 2002 for cod tagged in Placentia Bay are slightly lower than those observed in the previous three years (1999-2001) when estimates for most experiments exceeded 20% and the annual means ranged from 26% to 33%. Exploitation

seems to be declining in Placentia Bay with annual means declining from 33% in 1999 to 20% in 2002. This decline follows the reduction in landings seen over the past four years (see Fig. 2). However, note that not all of the exploitation of these cod occurs in Placentia Bay itself (see Table 5) and recent reductions in catch from the cod fishery in adjacent 3KL may also have lowered these estimates. Nonetheless, the 2002 estimates for 6 of 14 experiments conducted in 3Psc since the fall of 1998 remain high and exceed 20% (Table 4). The estimates for cod tagged prior to the fall of 1998 are based on very few recaptures (<5) and are consistently low; this may reflect growth and reduced selection of the remaining tagged fish from these experiments; most of these fish may have grown beyond the optimum selection size of gillnets which account for most of the catch. These recaptures were therefore not included when calculating annual means.

Among cod tagged in 3Psd since 1998, estimates of exploitation have been much lower than those for cod tagged inshore, ranging from 1.0 to 9.8% for individual experiments. The annual means have also been similar, ranging from 5% to 9%. Cod tagged in Halibut Channel (3Psh) have consistently shown lowest estimates of exploitation, with annual means typically around 1-3% and little variation among experiments in spite of substantial landings, particularly in 2000 (see Fig. 2).

Spatial and temporal distribution of recaptures

Annual summaries of the distribution of recaptures, grouped by unit area and year of release, are given in Table 5; in addition, plots showing the annual distribution of recaptures (only for tags where exact recapture positions were reported) by unit area of release are shown in Figs. 3A-3E.

Cod have been tagged offshore in 3Psd (Hermitage Channel and the southern edge of Burgeo Bank) in April in five of the previous six years (Fig. 3A); the exception was 2000 when no significant aggregations were located. Many of these tagged cod have dispersed widely from the tagging area with recaptures extending west and northward into 3Pn-4RS as far north as the Strait of Belle Isle (4Ra) within 3 months of release. Others migrated inshore and eastward along the south coast of Newfoundland into unit areas 3Psa, 3Psb, and 3Psc, and more rarely into southern 3L. The proportion of recaptures from 3Pn4RS relative to 3Ps has varied annually and appears to be higher from the 1998 and 2001-2002 releases compared to the 1999 releases. The 2001-2003 taggings in 3Psd were conducted somewhat later in April to coincide with the DFO research vessel survey in that area. A substantial proportion of the recaptures from these experiments have come from 3Pn4RS, suggesting that mixing may extend to mid-April in some years; however, the proportions of cod from each stock present in mid-April remains difficult to determine. In addition, the directed cod fishery in 3Pn4Rs was closed in 2003 making comparison with previous years more difficult. Few of the cod tagged in Burgeo Bank have been recaptured on the southeast corner of St. Pierre Bank, or in Halibut Channel, in spite of substantial landings, suggesting little inter-mixing between cod tagged in these two offshore regions during April. The lack of recaptures close to the tagging site in 3Psd can be attributed at least partly to this region being closed to directed cod fishing from November-April since 1998.

Most cod tagged near Pass Island and Poole's Cove, Fortune Bay, show strong inshore residency even among recaptures taken 4-5 years later, with most recoveries coming from within Fortune Bay or eastward into neighbouring Placentia Bay (Fig. 3B). There is little evidence of westward movement of these cod with only a few recaptures from 3Pn4RS especially from experiments

conducted later in spring (late May). These experiments may have included some migrant fish from areas to the west. Small proportions of cod tagged in Fortune Bay have also been recovered from more distant regions such as southern 3L, offshore 3Ps, and 3Pn4RS, but in general there are no strong indications of any progressive dispersal away from the tagging region over time.

A single experiment involving only 57 cod tagged in 3Psa has generated a small number of inshore recaptures in 3Ps west of the Burin Peninsula, with one offshore recapture in Halibut Channel (Fig 3C).

Cod have been tagged offshore in Halibut Channel (3Psh) during April in five consecutive years. (see Fig. 3D and Table 5). Recaptures have come mainly from three areas: (1) the slope edge at the bottom of Halibut Channel close to the area of release (3Psh), (2) shallow water on the south-east corner of St. Pierre Bank in unit areas (3Psf and 3Psh), or (3) inshore in Placentia Bay and around the Avalon Peninsula (3Psc and 3Lj/q/f). A few cod tagged in this region have been reported as recaptured in 3NO where the directed fishery for cod is still under moratorium, and single recaptures have been reported from 3K and 4R. Overall, the distribution of recaptures has been consistent for 5 years, although substantially fewer recaptures have been obtained from the 2000 and 2001 releases in Halibut Channel relative to those released in 1998 and 1999. Also, it is notable that there have consistently been few recaptures from the western portion of the inshore of 3Ps (i.e. 3Psa and 3Psb) in spite of substantial landings (see Fig. 2).

Cod tagged in Placentia Bay (Fig. 3C) have mostly been recaptured inshore within Placentia Bay or in neighbouring Fortune Bay. Typically over 80% of the recoveries have come from within Placentia Bay itself, even 5-6 years after tagging (Table 5). In each year, small proportions of recaptures have come from southern 3L, particularly in 1999, and more rarely northern 3L (i.e. 3La, 3Lb) or 3K. Most tagging experiments in Placentia Bay in spring have resulted in a small number of recaptures clustered at the slope edge at the bottom of the Halibut Channel, or scattered across St. Pierre Bank. However, the number of reported offshore recaptures from Placentia Bay tagging has been small in spite of substantial offshore landings (see Table 2A, Fig. 2).

Cod tagged on the NW edge of St. Pierre Bank have mostly been recovered only short distances away eastward on St. Pierre Bank, or inshore in Placentia Bay (Fig. 3A). There are no recoveries of these cod from 3Pn4RS, in contrast to those tagged in the Burgeo Bank-Hermitage Channel area about 25 miles to the northwest (see Fig. 3A).

Discussion

The updated results described herein are generally similar to those given in our previous analyses (Brattey et al. 2002a), and again show limited mixing of cod from different portions of the 3Ps stock area as well as higher exploitation of adult cod in the inshore. There are indications of strong inshore residency among fish tagged in spring in Fortune Bay and Placentia Bay. These fish appear to disperse along the inshore during summer, particularly in an easterly direction, with their distribution extending into 3L in some years. There appears to be limited offshore movement of these cod with only a few offshore recaptures even several years after release. These inshore sub-components, particularly in Placentia Bay, are supplemented during late spring, summer, and fall by seasonal migrants from offshore areas. The tagging shows that the

inshore catch comprises a mixture of cod that includes inshore fish as well as migratory offshore cod from Burgeo Bank, St. Pierre Bank, and the Halibut Channel. In contrast, the offshore catch (3Ps/e/f/g/h) appears to be comprised mainly of fish that reside on St. Pierre Bank and in Halibut Channel throughout the year.

Results from tagging in the Burgeo area suggests that there may be mixing of 3Ps cod with those from 3Pn4RS even as late as mid-April, suggesting that spring research vessel survey catches may include some non-3Ps fish. However, the extent of mixing appears to vary annually and the precise stock affinity of these fish remains difficult to determine (Campana et al. 1999; Chouinard, 2000; Bérubé and Fréchet 2001).

Although the tagging in the Burgeo area suggests that there may be mixing with Gulf cod even as late as mid-April in some years, our estimates of exploitation for cod tagged in this region are low and do not suggest cod in the Burgeo Bank area at that time, irrespective of their stock affinity, have been heavily exploited. In addition, catches from the "mixing" area itself have been low in recent years due to seasonal closures and the switch from a competitive fishery to individual quotas. Reported commercial landings from 3Psa/d combined during November-April 2002/2003 were only 260 t. These data suggest that potential removals of 3Pn4RS cod from this area, particularly in 2001 and 2002, are relatively small and likely to have little influence on the dynamics of that stock.

In contrast, cod tagged in Placentia Bay have been more heavily exploited and there is a concentration of fishing effort in this portion of the stock area, particularly in July and again in November-December in most years. Local fishers have reported that the abundance of cod in Placentia Bay in late fall increased considerably during the moratorium. Catch rates in Placentia Bay declined after the fishery reopened in 1997, but have remained similar over the past 3 years (Brattey et al. 2002b), suggesting that current exploitation rates are preventing local rebuilding of this component of the stock. Our estimates of exploitation for cod in Placentia Bay during 2002 (20%) tend to be lower than those for the preceding three years and correlate well with the reduction in landings both overall and from within Placentia Bay. However, catch rate indices from sentinel and logbooks for the <35' sector have remained low but largely unchanged for the past three years. For this local stock to rebuild it appears that further reductions in exploitation (and/or better recruitment) would be required. In contrast, catch rate indices (sentinel line-trawl and under 35" line-trawl) for Fortune Bay (3Psb) as a whole have been quite stable in recent years (see Brattey et al 2003). Our tagging data suggest that overall exploitation among cod tagged in Fortune Bay has been reasonable, although some high estimates have been obtained for the inner reaches of Fortune Bay.

The estimates of exploitation for the offshore areas in 3Ps are much lower than those for other regions, in spite of substantial offshore landings ranging from 4,000 - 12,000 t per annum during 1998-2002 (Fig 2). As in the previous analyses (Brattey et al. 2002a) there are concerns that the estimates for the offshore may be too low. Possible reasons include, estimates of reporting rate that are too high, limited tagging coverage (both spatial and temporal), restricted distribution of fishing activity in the offshore, and possibly lower survival of fish caught for tagging offshore in deep (>200m) water (see Brattey and Cadigan, in press). There have been substantial landings in some portions of the offshore where little or no tagging has been conducted (i.e. 3Pse/f, see Table 2) suggesting that there are offshore stock components that contribute significantly to the fishery that have not been tagged. More extensive tagging coverage, particularly on St. Pierre

Bank during fall, would clearly be beneficial to determine the origins of these cod and provide more reliable estimates of offshore exploitation.

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Table 1. Summary of details for cod tagging experiments conducted in NAFO Subdiv. 3Ps during 1997-2003 (PB=Placentia Bay, FB=Fortune Bay, HB=Hermitage Bay).

Year & expt no.	DFO Stat. area	Area of release	Dates	Gear	Depth (m)	Number tagged	Mean length (cm)
1997-001	3Psc	Bar Haven, NW PB	9-12 Apr.	handline	48-60	996	62.1
1997-002	3Psc	Clattice Hbr., NW PB	10 Apr.	handline	58-60	966	52.3
1997-004	3Psc	Bar Haven, NW PB	17-18 May	handline	50	817	65.0
1997-005	3Psc	St. Bride's, SE PB	25-28 May	handline	40	709	66.4
1997-006	3Psc	Oderin Bank, W PB	24-26 Jun.	handline	40	963	58.9
1997-008	3Psc	Lord's Cove, SW PB	25 Jun.-18 Jul.	trap/handline	18-40	793	53.5
1997-015	3Psc	Iona Islands, E PB	6-8 Nov.	handline	30-50	778	61.3
1998-001	3Psh	Halibut Channel	2-5 Apr.	otter trawl	181-307	1842	63.9
1998-002	3Psd	Hermitage Channel	5-7 Apr.	otter trawl	231-344	1352	53.9
1998-003	3Psc	Bar Haven, NW PB	22-25 April	handline	21-50	2073	61.0
1998-004	3Psc	Paradise Sound, W PB	27-29 April	otter trawl	151-206	1212	60.8
1998-005	3Psc	Wareham Rock, NW PB	May 1-3	handline	41-53	1037	61.9
1998-006	3Psb	Pool's Cove, FB	May 20-29	handline	67	938	57.5
1998-007	3Psc	Bar Haven, NW PB	19-24 Oct.	h'line/otter trl.	41-60	511	60.3
1998-008	3Psc	Eastern Channel, PB	17-22 Oct.	handline	52-80	883	58.8
1999-003	3Psb	South of Pass Island, FB	8 Apr.	otter trawl	211-217	1293	57.0
1999-004	3Psc	head of Placentia Bay	29 Apr.-7 May	handline	20-70	2422	63.2
1999-002	3Psd	Hermitage Channel	4-7 Apr.	otter trawl	192-322	464	59.8
1999-001	3Psh	Halibut Channel	1-3 Apr.	otter trawl	149-239	1808	68.0
1999-039	3Psc	head of Placentia Bay	8-17 Nov	h'line/otter tr'l	50	2152	63.0
1999-043	3Psa	Hermitage Bay	30 Nov-1 Dec	handline	50	57	52.9
2000-001	3Psh	Halibut Channel	1-7 Apr	otter trawl	203-259	1044	85.8
2000-003	3Psd	Burgeo Bank	4-Apr	otter trawl	212-318	5	77.0
2000-004	3Psb	Pass Island	5-7 Apr	otter trawl	136-220	1665	53.1
2000-006	3Psb	Pool's Cove, FB	17-19 Apr	line-trawl	60-112	752	55.0
2000-007	3Psc	inner Placentia Bay	26 Apr - 6 May	handline	16-50	2494	60.5
2000-008	3Psc	inner Placentia Bay	27 Apr - 4 May	otter trawl	30-107	528	59.2
2000-033	3Psc	Bar Haven, PB	5-12 Nov.	handline	33-55	1165	59.0
2000-034	3Psc	Saturday Ledge, PB	10-12 Nov.	otter trawl	35-55	792	58.7
2000-035	3Psc	Eastern Channel, PB	13-15 Nov.	handline	35-63	1212	58.7
2001-001	3Psb	Pool's Cove, FB	9-11 Jan.	handline	55-92	200	57.5
2001-002	3Psb	Pool's Cove, FB	9-11 Jan.	linetrawl	73-92	388	56.1
2001-003	3Psh	Halibut Channel	12-14 Apr.	otter trawl	170-248	1144	80.8
2001-006	3Psd/a	Burgeo Bank	15-17 Apr.	otter trawl	179	999	53.8
2001-007	3Psd	NW St. Pierre Bank	16-17 Apr.	otter trawl	186-193	666	89.0
2001-008	3Psb	Pass Island, FB	18 Apr.	otter trawl	178-224	477	54.8
2001-009	3Psb	Fortune Bay	25-26 Apr.	handline	50-185	60	52.8
2001-010	3Psc	inner Placentia Bay	28 Apr.-6 May	otter trawl	35-230	1704	57.1
2001-011	3Psc	inner Placentia Bay	28 Apr.-7 May	handline	30-60	2273	58.7
2002-001	3Psb	Pool's Cove, FB	8-10 Jan.	handline	31-69	408	54.2
2002-002	3Psb	Pool's Cove, FB	8-10 Jan.	linetrawl	60-76	223	55.4
2002-003	3Psh	Halibut Channel	11-18 Apr.	otter trawl	150-279	1509	56.5
2002-004	3Psb	Pass Island, FB	13-14 Apr.	otter trawl	219-239	1792	54.0
2002-006	3Psd	SE Burgeo Bank	14-15 Apr.	otter trawl	136-369	963	64.8
2002-007	3Psc	inner Placentia Bay	27 Apr.-7 May	handline	20-45	1832	55.5
2002-008	3Psc	inner Placentia Bay	28 Apr.-7 May	otter trawl	17-48	1399	56.4
2002-012	3Psb	Grand Bank, FB	18 Jun.	handline	67	138	52.0
2002-024	3Psc	inner Placentia Bay	12-18 Nov.	handline	29-51	1676	55.6
2003-002	3Psh	Halibut Channel	12-13 Apr.	otter trawl	184-295	133	53.4
2003-003	3Psb	Pass Island, FB	14-15 Apr.	otter trawl	208-231	1481	52.2
2003-004	3Psd	Burgeo Bank	15-16 Apr	otter trawl	277-347	878	63.0
2003-005	3Psc	Placentia Bay	28 Apr.-11 May	handline	14-70	3427	55.5
2003-006	3Psb	Fortune Bay	16-22 Jun.	hand-line	39-80	1384	54.0
2003-007	3Psb	Fortune Bay	16-22 Jun.	h'line/otter trawl	34-160	630	54.4

Table 2A. Reported monthly landings by unit area for NAFO Subdiv. 3Ps during 2002 and January-September 2003. (including French, recreational and sentinel fisheries).

2002	Inshore			Offshore					
Month	3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	Totals
Jan	1.4	115.5	242.5	63.0	0.0	0.0	0.4	862.2	1285.0
Feb	16.7	25.5	102.2	28.1	0.0	0.0	20.0	869.1	1061.6
Mar	46.4	39.0	24.1	27.3	0.0	0.0	16.2	103.5	256.5
Apr	3.9	0.7	0.1	12.8	0.0	0.0	1.7	18.3	37.6
May	40.3	199.4	114.6	0.4	0.0	0.0	3.2	0.9	358.8
Jun	91.5	317.7	506.4	10.9	8.0	0.3	2.3	11.6	948.6
Jul	170.8	461.8	1475.8	37.2	121.2	78.4	0.8	10.1	2356.1
Aug	198.6	342.2	511.9	34.8	402.3	287.9	14.9	46.2	1838.7
Sep	286.2	286.7	352.0	30.8	474.6	436.3	10.0	72.3	1948.8
Oct	327.1	98.0	273.3	46.4	302.2	201.2	11.9	79.3	1339.4
Nov	153.4	204.5	986.8	7.6	79.7	135.7	10.3	639.9	2217.8
Dec	16.6	210.9	302.2	58.3	0.0	4.2	0.1	578.1	1170.4
Totals	1352.9	2302.0	4891.9	357.5	1388.1	1143.9	91.8	3291.5	14819.4

2003	Inshore			Offshore					
Month	3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	Totals
Jan	1.9	197.3	90.3	5.9	0.0	452.0	0.2	708.4	1455.9
Feb	1.2	53.4	1.0	19.9	0.2	479.0	0.2	698.3	1253.2
Mar	0.2	1.2	0.0	1.0	0.0	0.0	0.0	45.6	48.0
Apr	1.5	0.0	0.3	0.0	0.0	0.0	0.0	17.8	19.7
May	58.5	201.2	94.7	0.0	0.0	0.0	0.0	1.8	356.2
Jun	97.2	235.3	774.5	0.8	0.1	0.5	0.2	14.9	1123.6
Jul	147.6	315.9	1275.8	23.5	2.3	30.3	0.0	19.4	1814.8
Aug	125.1	256.4	535.3	8.2	1.2	28.5	0.0	13.4	968.1
Sep	285.3	1113.2	1172.8	8.9	0.0	14.3	0.0	0.0	2594.6
Oct	.	.	.	.	.	.	.	.	
Nov	.	.	.	.	.	.	.	.	
Dec	.	.	.	.	.	.	.	.	
Totals	718.5	2374.0	3944.7	68.1	3.8	1004.6	0.6	1519.5	9633.9

Table 2B. Reported landings of cod from inshore unit areas in NAFO Divs. 3KL during 1998-2002.

Year	3Ka	3Kd	3Kh	3Ki	3La	3Lb	3Lf	3Lj	3Lq	Totals
1998	5.4	121.8	660.9	1331.0	1112.6	648.9	410.6	402.0	146.7	4840.0
1999	23.5	205.4	1100.3	2299.0	1462.4	1685.8	701.6	697.5	268.0	8443.5
2000	13.2	56.7	204.1	1187.8	1476.6	1441.9	398.4	451.1	210.8	5440.5
2001	26.9	183.6	439.8	1117.3	1546.4	2041.7	592.2	485.7	434.2	6867.6
2002	8.3	37.2	133.5	444.1	1150.0	1503.4	304.3	287.9	284.6	4153.3

Table 2C. Reported landings of cod from inshore unit areas in NAFO Divs. 4RS and subdiv 3Pn during 1997-2002.

Year	3PN	4Ra	4Rb	4Rc	4Rd	4Ru	4Si	4Ss	4Su	4Sv	4Sw	4Sx	4Sy	4Sz	Totals
1997	2005.8	805.8	600.2	593.4	299.0	0.0	0.2	7.3	0.0	140.6	327.3	7.0	1.2	4.1	4791.8
1998	870.1	386.5	366.6	281.3	635.8	0.0	0.2	3.7	0.0	60.6	476.3	26.7	0.0	2.6	3110.6
1999	1164.6	1551.3	1478.1	908.2	944.0	0.0	0.9	21.1	1.0	123.9	632.0	43.9	19.7	1.7	6890.4
2000	1478.5	1215.0	1438.8	728.4	800.1	1.6	2.6	29.7	13.3	179.6	660.1	80.2	13.1	1.1	6642.0
2001	1739.6	1310.4	1268.8	995.4	717.0	16.5	0.3	22.9	17.9	252.4	569.6	26.2	12.4	0.8	6950.1
2002	1218.1	1125.5	1520.3	838.4	496.0	42.3	1.4	28.3	4.2	126.2	703.4	30.4	7.2	0.1	6141.8

Table 3. Annual summary of reported recaptures (all tag types combined) for cod tagged and released in NAFO Subdiv. 3Ps during 1997-2003 (PB=Placentia Bay, FB=Fortune Bay, HB=Hermitage Bay).

Year & expt no.	DFO Stat. area	Area of release	Dates of release	Number tagged	Reported recaptures 1997	1998	1999	2000	2001	2002	*2003	unk'n
1997-001	3Psc	Bar Haven, NW PB	9-12 Apr.	996	78	69	72	34	8	3	1	8
1997-002	3Psc	Clattice Hbr., NW PB	10 Apr.	966	91	42	53	26	7	5	0	7
1997-004	3Psc	Bar Haven, NW PB	17-18 May	817	103	43	84	49	5	5	0	6
1997-005	3Psc	St. Bride's, SE PB	25-28 May	709	27	46	86	41	8	1	1	5
1997-006	3Psc	Oderin Bank, W PB	24-26 Jun.	963	16	57	36	16	10	0	0	5
1997-008	3Psc	Lord's Cove, SW PB	25 Jun.-18 Jul.	794	28	69	50	26	13	3	1	2
1997-015	3Psc	Iona Islands, E PB	6-8 Nov.	784	0	39	89	32	9	2	0	5
				6029	343	365	470	224	60	19	3	38
1998-001	3Psh	Halibut Channel	2-5 Apr.	1842	.	24	23	16	7	4	1	3
1998-002	3Psd	Hermitage Channel	5-7 Apr.	1352	.	39	50	20	10	3	0	2
1998-003	3Psc	Bar Haven, NW PB	22-25 April	2073	.	124	310	140	34	8	1	19
1998-004	3Psc	Paradise Sound, W PB	27-29 April	1212	.	152	191	99	20	3	2	15
1998-005	3Psc	Wareham Rock, NW PB	May 1-3	1037	.	81	208	90	25	6	0	13
1998-006	3Psb	Pool's Cove, FB	May 20-29	938	.	87	91	43	25	13	2	1
1998-008	3Psc	Bar Haven, NW PB	19-24 Oct.	511	.	6	79	37	22	9	1	2
1998-009	3Psc	Eastern Channel, PB	17-22 Oct.	883	.	29	102	84	37	18	1	9
				9848		542	1054	529	180	64	8	64
1999-001	3Psh	Halibut Channel	1-3 Apr.	1808	.	.	39	44	20	13	5	3
1999-002	3Psd	Hermitage Channel	4-7 Apr.	464	.	.	29	12	2	6	0	0
1999-003	3Psb	South of Pass Island, FB	8 Apr.	1293	.	.	76	59	31	18	2	2
1999-004	3Psc	head of Placentia Bay	29 Apr.-7 May	2422	.	.	400	273	110	32	8	30
1999-039	3Psc	head of Placentia Bay	8-17 Nov	2152	.	.	68	367	123	42	3	23
1999-043	3Psb	Hermitage Bay	30 Nov-1 Dec	57	.	.	1	6	2	1	0	0
				8196			613	761	288	112	18	58
2000-001	3Psh	Halibut Channel	1-7 Apr	1044	.	.	.	2	12	2	1	0
2000-003	3Psd	Burgeo Bank	4-Apr	5	.	.	.	0	0	0	0	0
2000-004	3Psb	Pass Island	5-7 Apr	1665	.	.	.	92	44	44	12	1
2000-006	3Psb	Pool's Cove, FB	17-19 Apr	752	.	.	.	60	62	34	7	4
2000-007	3Psc	inner Placentia Bay	26 Apr - 6 May	2494	.	.	.	312	269	105	9	22
2000-008	3Psc	inner Placentia Bay	27 Apr - 4 May	528	.	.	.	65	43	25	2	5
2000-033	3Psc	Bar Haven, PB	5-12 Nov.	1165	.	.	.	43	152	40	8	6
2000-034	3Psc	Saturday Ledge, PB	10-12 Nov.	792	.	.	.	40	80	44	7	8
2000-035	3Psc	Eastern Channel, PB	13-15 Nov.	1212	.	.	.	50	129	39	10	8
				9657				664	791	333	56	54
2001-001	3Psb	Pool's Cove, FB	9-11 Jan.	200	.	.	.	.	25	13	2	0
2001-002	3Psb	Pool's Cove, FB	9-11 Jan.	388	.	.	.	.	52	25	5	3
2001-003	3Psh	Halibut Channel	12-14 Apr.	1144	.	.	.	.	10	13	5	0
2001-006	3Psd/a	Burgeo Bank	15-17 Apr.	999	.	.	.	.	55	32	5	1
2001-007	3Psd	NW St. Pierre Bank	16-17 Apr.	666	.	.	.	.	25	9	3	1
2001-008	3Psb	Pass Island, FB	18 Apr.	477	.	.	.	.	14	15	5	0
2001-009	3Psb	Fortune Bay	25-26 Apr.	60	.	.	.	.	4	5	2	0
2001-010	3Psc	inner Placentia Bay	28 Apr.-6 May	1704	.	.	.	.	215	173	22	20
2001-011	3Psc	inner Placentia Bay	28 Apr.-7 May	2273	.	.	.	.	326	185	24	14
2001-025	3Psa	Ramea	1 Aug.	7	.	.	.	.	0	1	0	0
2001-027	3Psc	inner Placentia Bay	22 Nov.	350	.	.	.	.	5	47	6	2
				8268					731	518	79	41
2002-001	3Psb	Pool's Cove, FB	8-10 Jan.	408	.	.	.	.	.	32	18	0
2002-002	3Psb	Pool's Cove, FB	8-10 Jan.	223	.	.	.	.	.	31	8	0
2002-003	3Psh	Halibut Channel	11-18 Apr.	1509	.	.	.	.	.	11	3	0
2002-004	3Psb	Pass Island, FB	13-14 Apr.	1792	.	.	.	.	.	46	20	0
2002-006	3Psd	SE Burgeo Bank	14-15 Apr.	963	.	.	.	.	.	13	3	0
2002-007	3Psc	inner Placentia Bay	27 Apr.-7 May	1832	.	.	.	.	.	215	58	3
2002-008	3Psc	inner Placentia Bay	28 Apr.-7 May	1399	.	.	.	.	.	185	54	2
2002-012	3Psb	Grand Bank, FB	18 Jun.	138	.	.	.	.	.	9	2	0
2002-024	3Psc	inner Placentia Bay	12-18 Nov	1676 #						69	41	0
				9940						611	207	5
2003-002	3Psh	Halibut Channel	12-13 Apr.	133	.	.	.	.	.	.	1	0
2003-003	3Psb	Pass Island, FB	14-15 Apr.	1481	.	.	.	.	.	.	29	0
2003-004	3Psd	Burgeo Bank	15-16 Apr	878	.	.	.	.	.	.	7	0
2003-005	3Psc	Placentia Bay	28 Apr.-11 May	3427	.	.	.	.	.	.	127	0
2003-006	3Psb	Fortune Bay	16-22 Jun.	1384	.	.	.	.	.	.	41	0
2003-007	3Psb	Fortune Bay	17-27 Jun.	630	.	.	.	.	.	.	7	0
				7933							212	0

* tags received up to 30 Sept. 2003

Table 4. Annual estimates of exploitation (harvest rates) by experiment for cod tagged in NAFO Subdiv. 3Ps during 1997-2003 Recaptures were adjusted to account for reporting rate and releases were adjusted to account for tagging mortality, tag loss and assumed natural mortality. Shaded cells represent estimates for experiments conducted during the fishing season and account for only a portion of exploitation in the year of release. Boxed cells indicate values used to compute annual means for each area of release. See text for further details.

					Reported landings (t)						
					9,045	19,694	28,111	25,100	16,546	14,819	*9634
DFO Stat. area	Year & expt no.	Area of release	Dates	Number tagged	Exploitation rates (% harvested) 1997	1998	1999	2000	2001	2002	*2003
3Psa	1999-043	Hermitage Bay	30 Nov-1 Dec	57			3.4	22.1	12.6	7.8	0.0
"	2001-025	Ramea	1-Aug	7			0.0	0.0	0.0	33.7	0.0
			Annual means				0.0	0.2	0.1	0.3	
3Psb	1998-006	Poole's Cove, FB	20-29 May	938		13.3	21.7	13.9	12.5	8.7	1.9
"	1999-003	Pass Island, FB	8-Apr	1293			10.7	10.1	7.8	5.9	1.1
"	2000-004	Pass Island	5-7 Apr	1665				8.3	5.7	7.2	3.3
"	2000-006	Poole's Cove, FB	17-19 Apr	752				11.8	18.4	14.7	5.5
"	2001-001	Poole's Cove, FB	9-11 Jan	200					25.9	22.6	6.6
"	2001-002	Poole's Cove, FB	9-11 Jan	388					28.5	26.0	9.3
"	2001-008	Pass Island, FB	18-Apr	477					4.6	6.3	3.3
"	2001-009	Fortune Bay	25-26 Apr	60					10.3	16.0	12.5
"	2002-001	Poole's Cove, FB	8-10 Jan	408						16.9	14.6
"	2002-002	Poole's Cove, FB	8-10 Jan	222						27.7	14.2
"	2002-004	Pass Island, FB	13-14 Apr	1792						3.7	2.6
"	2002-012	Grand Bank, FB	18-Jun	138						9.3	3.2
"	2003-003	Pass Island, FB	14-15 Apr	1481							3.5
"	2003-006	Fortune Bay	16-22 Jun	1384							4.7
"	2003-007	Fortune Bay	16-22 Jun	630							1.7
			Annual means			13.3	15.3	10.5	10.8	10.3	
3Psc	1997-001	Bar Haven, NW PB	9-12 Apr	996	11.9	16.7	27.8	16.6	6.3	2.7	1.5
"	1997-002	Clattice Hbr., NW PB	10-Apr	966	14.1	11.0	20.7	11.6	4.5	4.0	0.0
"	1997-004	Bar Haven, NW PB	17-18 May	817	17.7	14.2	38.9	33.5	6.2	8.3	0.0
"	1997-005	St. Bride's, SE PB	25-28 May	709	5.7	15.1	41.5	30.8	10.1	1.7	2.7
"	1997-006	Oderin Bank, W PB	24-26 Jun	963	2.8	14.0	13.8	7.6	5.7	0.0	0.0
"	1997-008	Lord's Cove, SW PB	25 Jun-18 Jul	793	6.5	22.7	26.1	19.2	15.3	5.1	2.8
"	1997-015	Iona Islands, E PB	6-8 Nov	778	0.0	11.4	38.5	21.4	9.6	3.1	0.0
"	1998-003	Bar Haven, NW PB	22-25 Apr	2073		9.6	35.7	25.1	10.2	3.4	0.7
"	1998-004	Paradise Sound, W PB	27-29 Apr	1212		20.3	41.9	37.5	15.1	3.6	3.8
"	1998-005	Wareham Rock, NW PB	1-3 May	1037		12.5	48.8	38.7	23.3	9.7	0.0
"	1998-008	Bar Haven, NW PB	19-24 Oct	511		2.1	37.5	25.6	27.0	18.1	3.9
"	1998-009	Eastern Channel, PB	17-22 Oct	883		5.4	29.1	35.7	28.7	25.4	2.5
"	1999-004	inner Placentia Bay	29 Apr.-7 May	2422			33.0	31.6	24.8	11.8	4.6
"	1999-039	inner Placentia Bay	8-17 Nov	2152			6.4	36.5	26.5	14.6	1.8
"	2000-007	inner Placentia Bay	26 Apr - 6 May	2494				19.8	27.2	16.7	2.6
"	2000-008	inner Placentia Bay	27 Apr - 4 May	528				19.1	20.0	17.5	2.6
"	2000-033	Bar Haven, PB	5-12 Nov	1165				6.2	31.1	14.6	5.2
"	2000-034	Saturday Ledge, PB	10-12 Nov	792				8.7	26.2	23.7	7.3
"	2000-035	Eastern Channel, PB	13-15 Nov	1212				6.6	25.3	13.8	5.9
"	2001-010	inner Placentia Bay	28 Apr.-6 May	1704					21.9	27.0	7.0
"	2001-011	inner Placentia Bay	28 Apr.-7 May	2273					24.3	21.7	5.4
"	2001-027	western Channel, PB	22-23 Nov	350					2.2	31.1	8.6
"	2002-007	inner Placentia Bay	27 Apr - 7 May	1832						19.0	9.6
"	2002-008	inner Placentia Bay	28 Apr - 7 May	1399						21.8	11.9
"	2002-024	inner Placentia Bay	12-18 Nov	1676						6.5	6.4
"	2003-005	inner Placentia Bay	28 Apr.-11 May	3427							5.9
			Annual means		14.3	14.3	33.4	29.8	25.5	20.0	
3Psd	1998-002	Hermitage Channel	5-7 Apr	1352		4.4	8.5	4.3	2.8	1.0	0.0
"	1999-002	Hermitage Channel	4-7 Apr	464			10.2	5.9	1.3	5.1	0.0
"	2001-006	Burgeo Bank	15-17 Apr	999					9.8	8.4	1.7
"	2001-007	NW St. Pierre Bank	16-17 Apr	666					5.6	3.1	1.6
"	2002-006	SE Burgeo Bank	14-15 Apr	963						2.2	0.7
"	2003-004	Burgeo Bank	15-16 Apr	878							1.5
			Annual means			4.4	8.9	4.7	6.6	4.8	
3Psh	1998-001	Halibut Channel	2-5 Apr	1842		2.1	2.8	2.1	1.1	0.8	0.3
"	1999-001	Halibut Channel	1-3 Apr	1808			3.8	5.0	2.9	2.4	1.3
"	2000-001	Halibut Channel	1-7 Apr	1044				0.3	2.0	0.4	0.3
"	2001-003	Halibut Channel	12-14 Apr	1144					1.4	2.0	1.1
"	2002-003	Halibut Channel	11-18 Apr	1509						1.2	0.4
"	2003-002	Halibut Channel	12-13 Apr	133							1.0
			Annual means			2.1	3.3	2.8	2.2	1.2	

* based on recorded catch and tags received up to 30 September 2003

Table 5. Annual distribution of recaptures of cod tagged and released in various regions of NAFO Subdiv. 3Ps during 1997-2003. Recaptures were adjusted by region-specific reporting rates obtained from a high-reward tagging study. Shaded cells give the percentage recaptured in the area of release. Values for 2003 are based on tags received 30 September 2003.

					% of annual recaptures												
Release area	Release Year	Number tagged	Recapture year	Adj. nos. recap'd	3K (Bonavista)	3LA (Trinity)	3LB (Concep'n)	3LF (E. Avalon)	3LJ (S. Avalon)	3LQ (G. Banks)	3NO	3PSA (Burgeo N)	3PSB (Fortune)	3PSC (Placentia)	3PSD (Burgeo S)	3PSOFF (offshore)	4RS3PN (Gulf)	UNK
3PSA	1999	57	1999	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
			2000	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.7	14.3	0.0	0.0	0.0	0.0	0.0
			2001	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
			2002	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
	2001	7	2001	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
3PSB	1998	939	1998	105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	70.5	18.1	0.0	0.0	3.8	0.0
			1999	111	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	65.8	19.8	0.0	0.0	5.4	1.8
			2000	52	0.0	0.0	0.0	0.0	1.9	0.0	0.0	3.8	73.1	19.2	0.0	1.9	0.0	0.0
			2001	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	53.3	26.7	0.0	0.0	3.3	0.0
			2002	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93.8	6.3	0.0	0.0	0.0	0.0
			2003	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
	1999	1293	1999	94	0.0	0.0	1.1	0.0	1.1	1.1	0.0	4.3	29.8	61.7	0.0	1.1	0.0	0.0
			2000	75	0.0	0.0	0.0	4.0	1.3	1.3	0.0	6.7	41.3	40.0	0.0	2.7	2.7	0.0
			2001	39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	20.5	66.7	0.0	2.6	0.0	2.6
			2002	22	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	13.6	68.2	0.0	4.5	9.1	0.0
			2003	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0
	2000	2415	2000	198	0.0	0.0	0.0	0.0	0.5	0.0	0.0	3.0	58.1	33.8	0.0	0.5	1.0	3.0
			2001	140	0.0	0.0	0.0	0.0	0.7	2.9	0.0	2.9	64.3	24.3	0.7	0.7	2.9	0.7
			2002	101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	51.5	38.6	0.0	1.0	0.0	1.0
			2003	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	20.0	0.0	0.0	0.0	0.0
	2001	1124	2001	121	0.0	0.0	0.8	0.0	0.8	4.1	0.0	2.5	61.2	28.9	0.0	0.0	0.0	1.7
			2002	76	0.0	0.0	0.0	0.0	0.0	1.3	0.0	5.3	67.1	23.7	0.0	0.0	0.0	2.6
			2003	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	55.6	27.8	0.0	0.0	5.6	5.6
	2002	2557	2002	151	0.0	0.0	0.0	0.0	0.7	0.0	0.0	2.6	57.0	33.8	0.0	0.0	1.3	4.6
			2003	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	70.0	23.3	0.0	5.0	0.0	0.0
	2003	3488	2003	101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	82.2	13.9	0.0	0.0	0.0	0.0
3PSC	1997	6028	1997	410	0.0	0.0	0.2	0.2	0.2	0.5	0.0	0.0	4.4	94.1	0.0	0.2	0.0	0.0
			1998	438	0.0	0.0	0.7	1.4	4.1	0.9	0.5	0.2	13.7	74.7	0.7	1.1	0.5	1.6
			1999	561	0.4	0.2	1.2	3.0	1.4	1.6	0.0	1.1	7.1	81.5	0.0	0.9	0.0	1.6
			2000	269	0.4	0.7	0.4	0.0	0.7	0.7	0.0	1.5	7.1	82.2	0.0	4.5	0.4	1.5
			2001	72	0.0	0.0	1.4	0.0	0.0	1.4	0.0	1.4	12.5	79.2	0.0	4.2	0.0	0.0
			2002	22	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	22.7	54.5	0.0	13.6	0.0	4.5
			2003	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
	1998	5715	1998	456	0.0	0.0	0.7	2.4	4.4	1.3	0.0	0.2	1.1	86.6	0.0	0.0	0.0	1.1
			1999	1030	0.3	0.5	2.3	2.3	1.7	1.3	0.0	0.2	4.4	84.9	0.0	0.8	0.0	1.4
			2000	530	0.6	0.2	0.8	0.4	0.4	2.1	0.0	0.8	4.9	88.3	0.0	1.1	0.0	0.6
			2001	159	1.3	0.6	0.0	0.6	1.3	4.4	0.0	0.0	3.8	84.9	0.0	2.5	0.0	0.6
			2002	51	0.0	2.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	88.2	0.0	2.0	0.0	3.9
			2003	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.9	57.1	0.0	0.0	0.0	0.0
	1999	4574	1999	589	0.0	0.0	0.8	0.5	0.8	0.7	0.0	0.0	0.8	95.6	0.0	0.0	0.0	0.7
			2000	795	0.0	0.0	0.3	0.1	0.5	1.1	0.0	0.0	3.1	94.5	0.0	0.1	0.0	0.3
			2001	291	0.0	0.3	0.3	0.7	1.0	3.4	0.0	0.0	2.4	88.3	0.0	2.1	0.0	1.4
			2002	92	0.0	0.0	1.1	0.0	1.1	2.2	0.0	0.0	7.6	84.8	0.0	1.1	0.0	2.2
			2003	13	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	84.6	0.0	7.7	0.0	0.0
	2000	6190	2000	643	0.0	0.0	0.0	0.0	0.5	1.1	0.0	0.0	1.7	95.8	0.2	0.0	0.0	0.9
			2001	851	0.0	0.0	0.5	0.7	0.9	4.3	0.0	0.1	1.3	90.7	0.0	0.8	0.0	0.6
			2002	318	0.0	0.3	0.0	0.3	0.0	1.9	0.0	0.3	3.5	89.0	0.3	3.1	0.0	1.3
			2003	46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	91.3	0.0	2.2	0.0	0.0
	2001	4323	2001	698	0.1	0.1	0.1	1.4	0.7	5.4	0.0	0.0	1.1	88.3	0.0	0.7	0.0	1.9
			2002	520	0.2	0.2	0.2	0.6	0.6	0.8	0.0	0.6	1.2	93.1	0.0	1.2	0.0	1.5
			2003	64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	87.5	0.0	9.4	0.0	1.6
	2002	4902	2002	592	0.0	0.0	0.0	0.2	0.0	1.0	0.0	0.2	0.0	96.5	0.0	0.0	0.0	0.2
			2003	194	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	5.7	91.2	0.0	1.5	0.0	0.0
	2003	3426	2003	152	0.0	0.0	0.0	0.7	0.0	0.7	0.0	0.0	0.0	98.7	0.0	0.0	0.0	0.0

cont'd.-

Table 6. The proportion of tags returned by year and region based on a high-reward tagging study and estimated using methods described by Cadigan and Brattey (2003). 3K_IN=NAFO unit areas 3Kd/h/i; 3L_INN=3La/b; 3L_INS=3Lf/j/q; 3Ps_OF=3Pse/f/g/h; 3Ps_PB=3Psc; 3Ps_WB=3Psa/b/d.

	Single tag reporting rates							Double tag reporting rates						
Region	1997	1998	1999	2000	2001	2002	2003	1997	1998	1999	2000	2001	2002	2003
3K_IN	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.90	0.90	0.90	0.90	0.90	0.90	0.90
3L_INN	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.90	0.90	0.90	0.90	0.90	0.90	0.90
3L_INS	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.90	0.90	0.90	0.90	0.90	0.90	0.90
3NO	0.71	0.71	0.71	0.86	0.86	0.86	0.68	0.79	0.79	0.79	0.95	0.95	0.95	0.76
3PN_4R	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.69	0.69	0.69	0.69	0.69	0.69	0.69
3Ps_OF	0.71	0.71	0.71	0.86	0.86	0.86	0.68	0.79	0.79	0.79	0.95	0.95	0.95	0.76
3Ps_PB	0.71	0.71	0.71	0.86	0.86	0.86	0.68	0.79	0.79	0.79	0.95	0.95	0.95	0.76
3Ps_WB	0.71	0.71	0.71	0.86	0.86	0.86	0.68	0.79	0.79	0.79	0.95	0.95	0.95	0.76

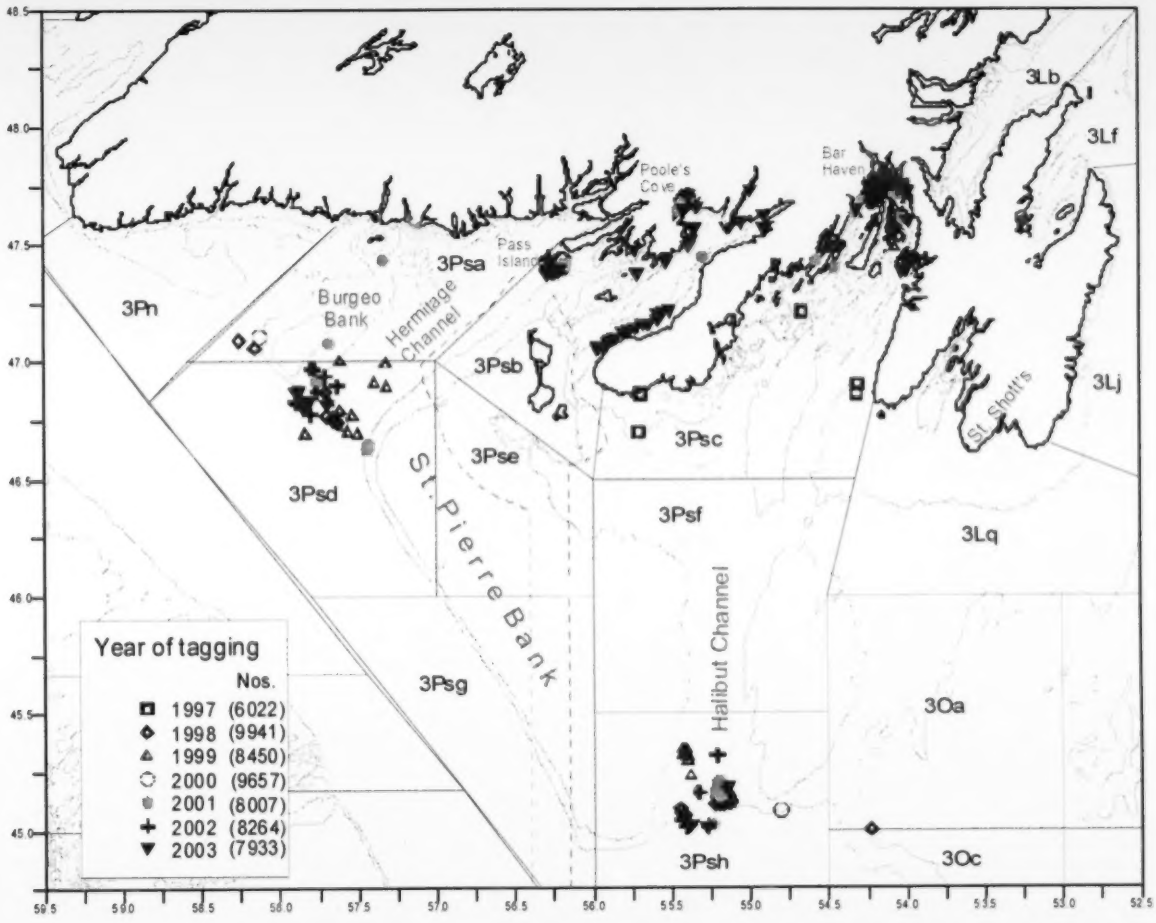


Fig. 1. Locations and total numbers of cod tagged each year off southern Newfoundland during 1997-2002, boundaries of unit areas, 100 m and 200 m depth contours (grey lines), and boundary of French economic zone (dashed line).

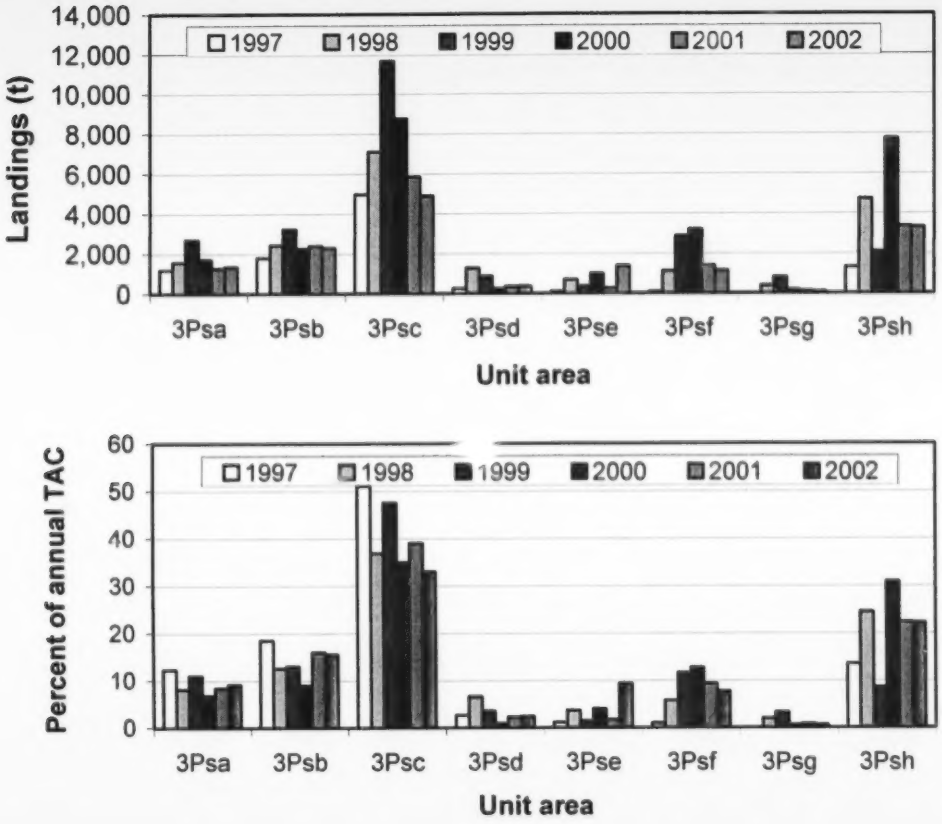
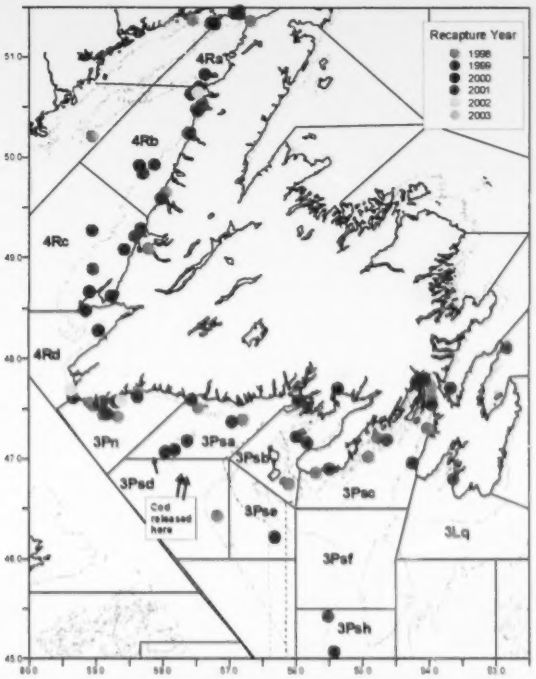
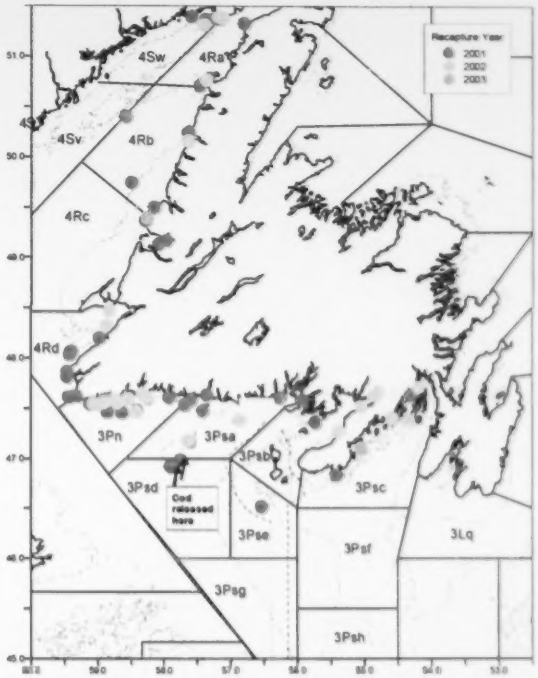


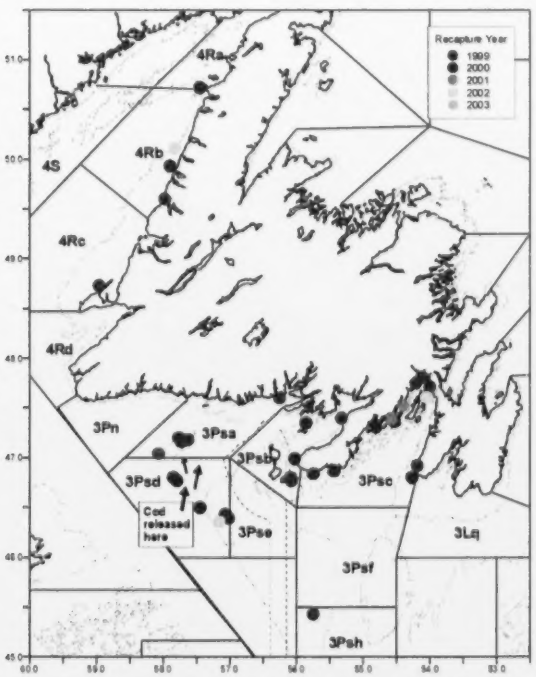
Fig. 2. Annual reported landings of cod by unit area from NAFO Subdiv. 3Ps during 1997-2002.



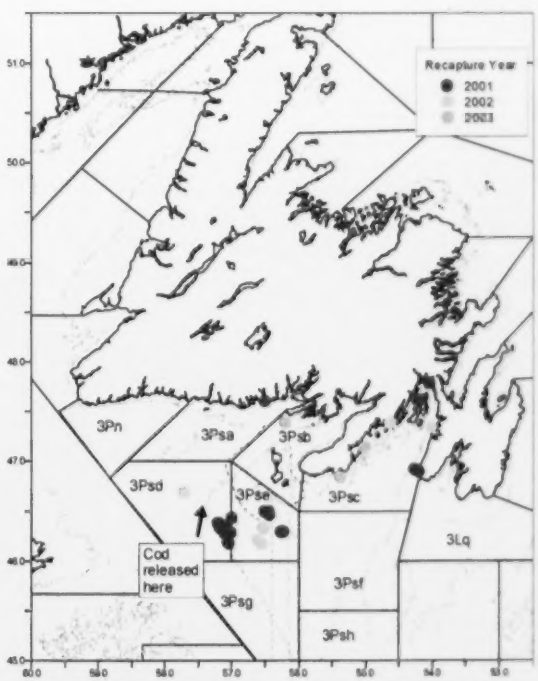
Reported recapture positions for cod tagged and released in Hermitage Channel - Burgeo Bank during 5-7 April 1998 (N=1352).



Reported recapture positions (dots) for cod tagged and released off Burgeo Bank-Hermitage Channel during 15-17 April 2001 (N=999).

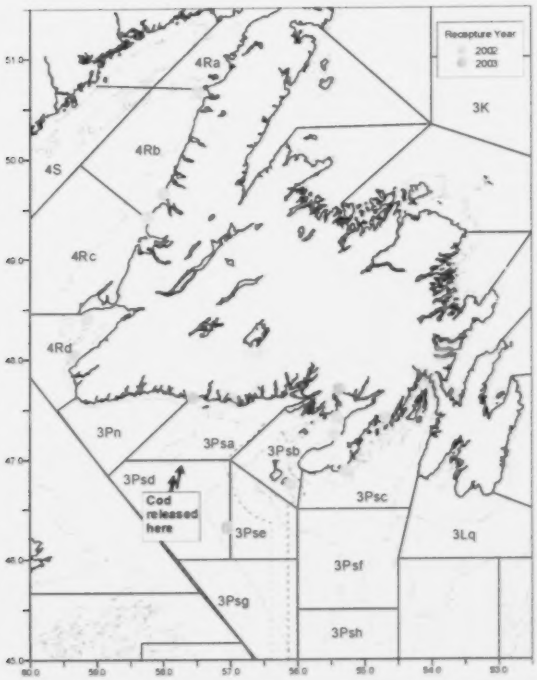


Reported recapture positions (dots) for cod tagged and released in Hermitage Channel - Burgeo Bank during 4-7 April 1999 (N=464).

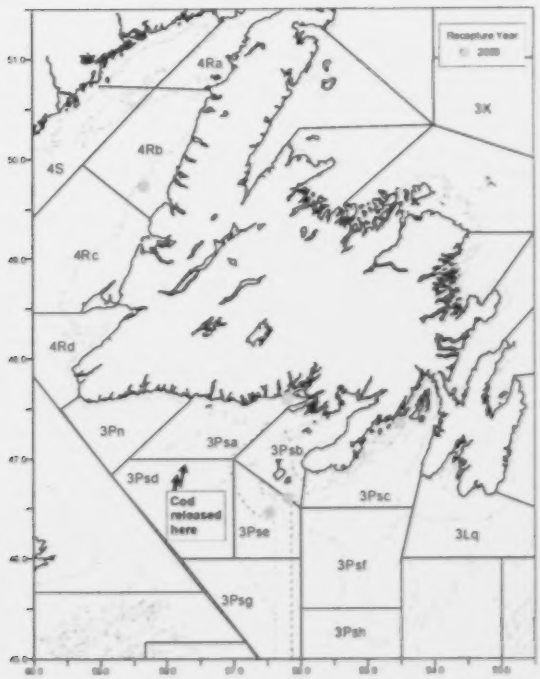


Reported recapture positions for cod tagged and released off northwestern St. Pierre Bank during 16-17 April 2001 (N=666).

Fig. 3A. Recaptures of cod tagged in 3Psd during April (1998, 1999, 2001-2003).

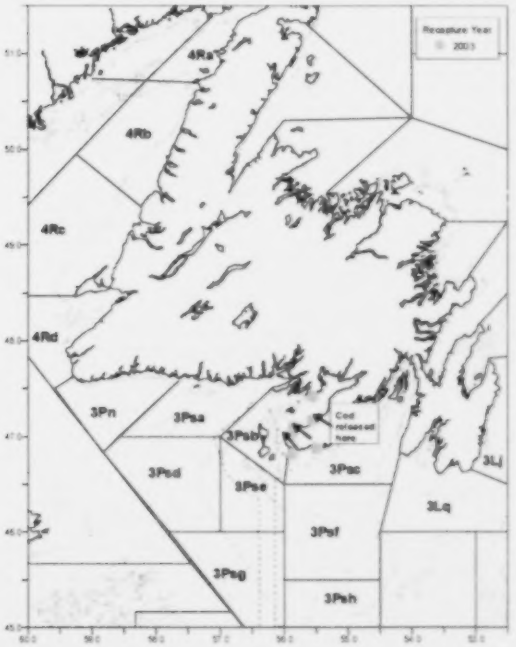


Reported recapture positions (dots) for cod tagged and released off SE Burgeo Bank during 14-15 April 2002 (N=963)

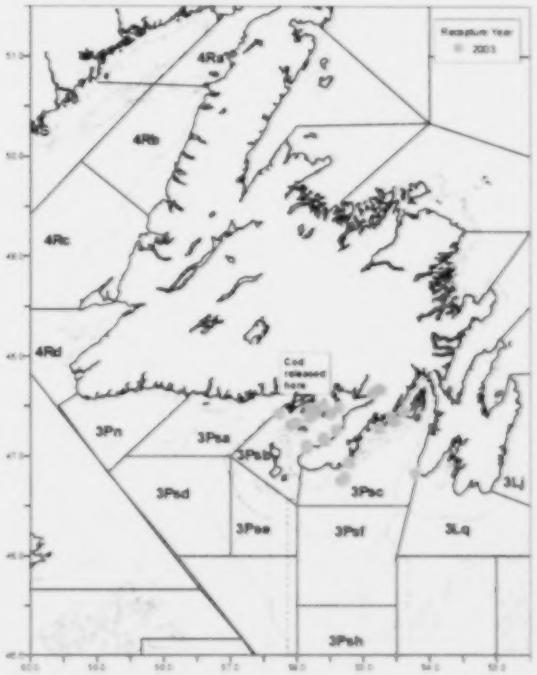


Reported recapture positions (dots) for cod tagged and released off SE Burgeo Bank during 15-16 April 2003 (N=878)

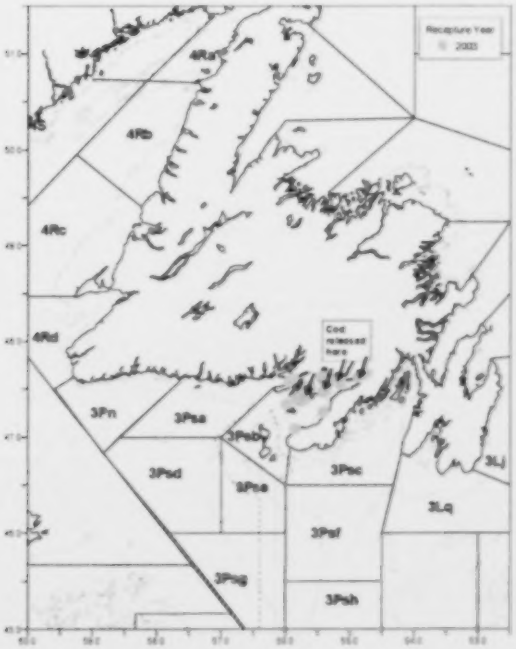
Fig. 3A. Recaptures of cod tagged in 3Psd during April (1998,1999, 2001-2003).



Reported recapture positions for cod tagged and released in 3Lb (south side Fortune Bay) during 17-27 June 2003 (N=630).



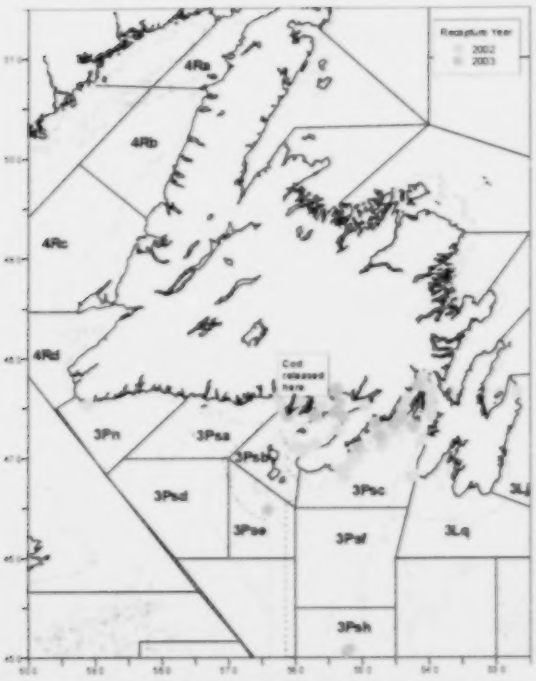
Reported recapture positions for cod tagged and released in 3Lb (off Pass Island) during 14-15 Apr 2003 (N=1481)



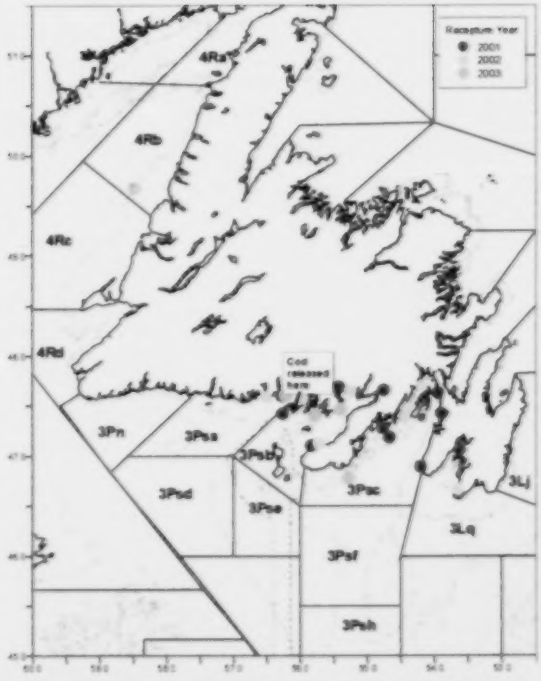
Reported recapture positions for cod tagged and released in 3Lb (north side Fortune Bay) during 16-22 June 2003 (N=1384).

Reported recapture positions for cod tagged and released in 3Lb (off Grand Bank) during 18 June 2002 (N=138).

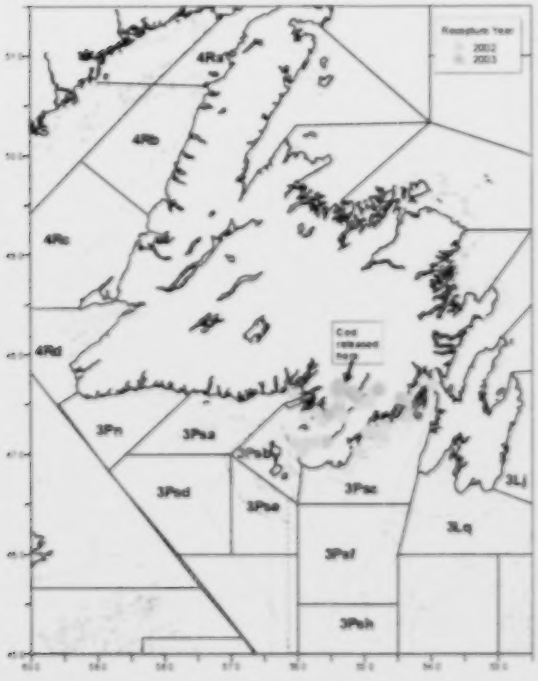
Fig. 3B. Recaptures of cod tagged in 3Psb during April-June (1998-2003).



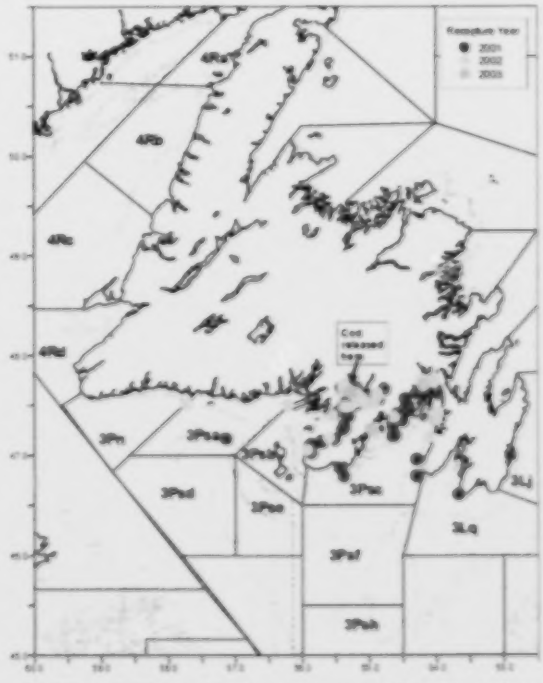
Reported recapture positions for cod tagged and released in 3Lb (off Pass Island) during 13-14 Apr 2002 (N=1792).



Reported recapture positions for cod tagged and released in 3Lb (off Pass Island) during 18 Apr 2001 (N=477).

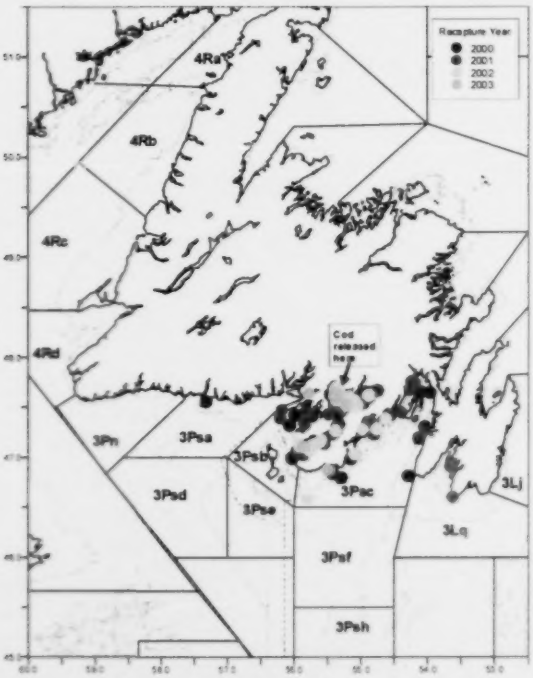


Reported recapture positions for cod tagged and released in 3Lb (off Poole's Cove) during 9-10 Jan 2002 (N=408 and N=223).

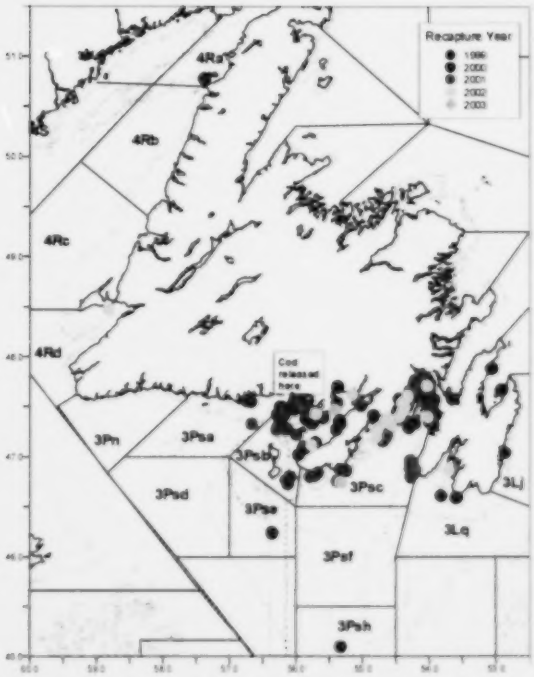


Reported recapture positions for cod tagged and released in 3Lb (off Poole's Cove) during 9-11 Jan 2001 (N=200 and N=368).

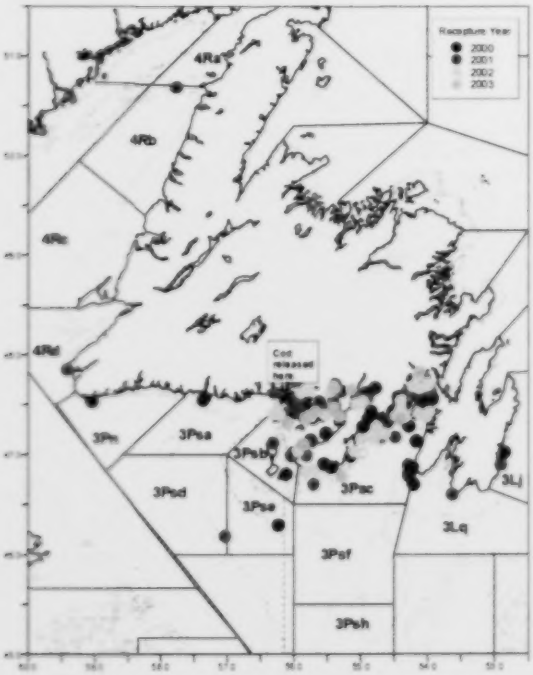
Fig. 3B. Recaptures of cod tagged in 3Psb during April-June (1998-2003).



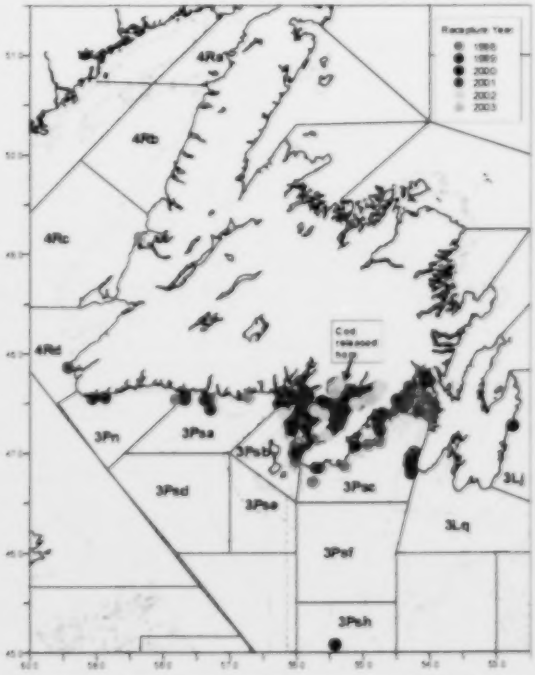
Reported recapture positions for cod tagged and released in 3Lb (off Poole's Cove) during 17-19 Apr 2000 (N=752)



Reported recapture positions for cod tagged and released in 3Lb (off Pass Island) during 6 Apr 1999 (N=1293)

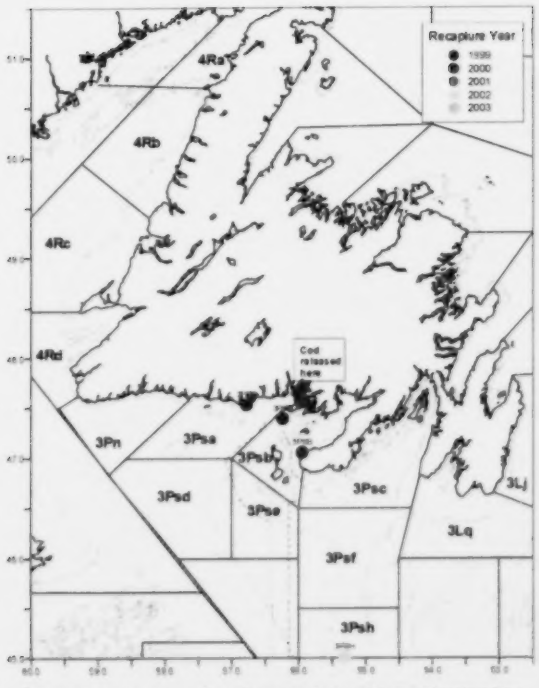


Reported recapture positions for cod tagged and released in 3Lb (off Pass Island) during 5-7 Apr 2000 (N=1665)



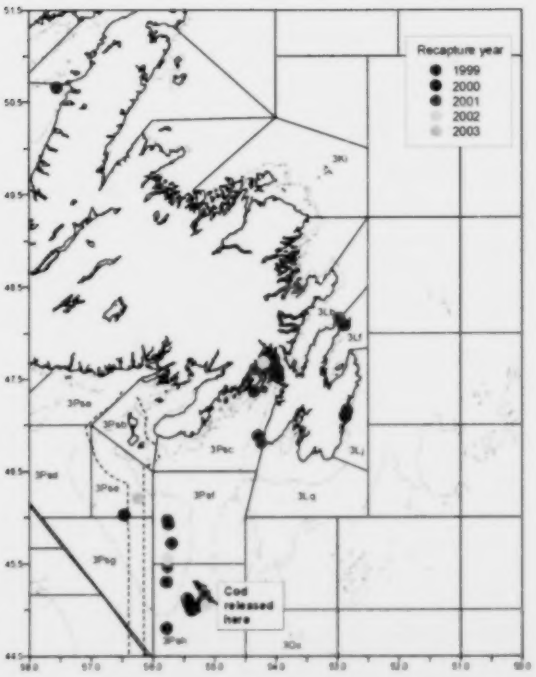
Reported recapture positions for cod tagged and released in 3Lb (off Poole's Cove) during 20-29 May 1998 (N=938)

Fig. 3B. Recaptures of cod tagged in 3Psb during April-June (1998-2003).



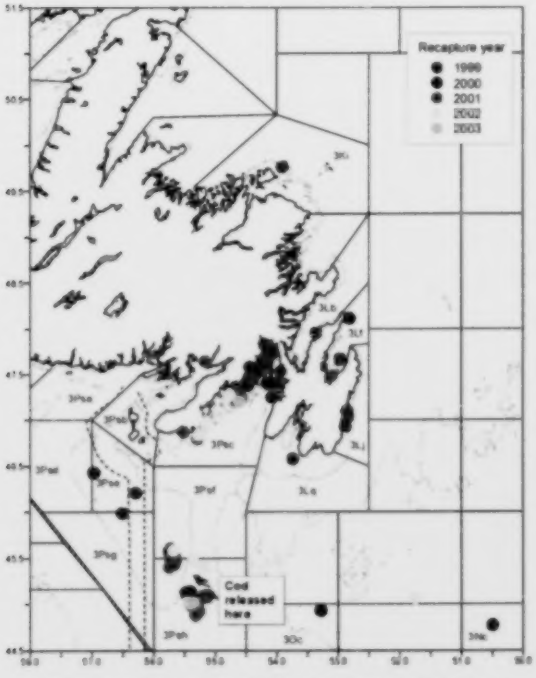
Reported recapture positions for cod tagged and released in 3La (Hermitage Bay) during 30 Nov - 1 Dec 1999 (N=57).

Fig. 3C. Recaptures of cod tagged in 3Psa during Nov-Dec 1999.



Reported recapture positions (dots) for cod tagged and released in Halibut Channel during 1-3 April 1999 (N=1808).

Reported recapture positions (dots) for cod tagged and released in Halibut Channel during 1-3 April 2000 (N=1044).



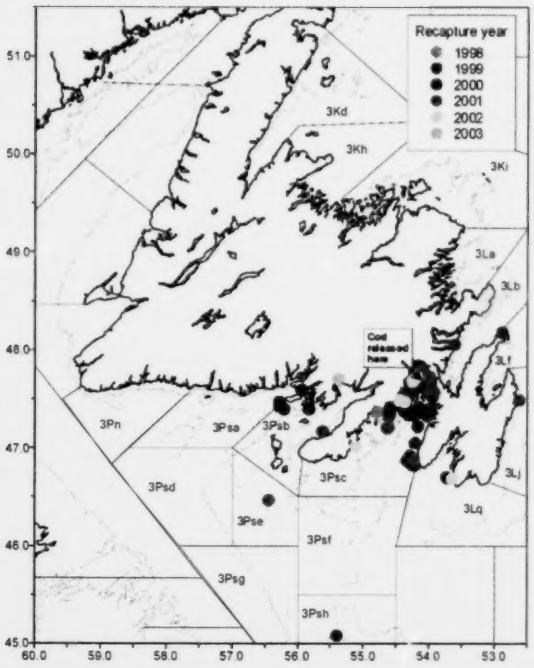
Reported recapture positions (dots) for cod tagged and released in Halibut Channel during 1-3 April 1999 (N=1808).

Reported recapture positions (dots) for cod tagged and released in Halibut Channel during 12-14 April 2001 (N=1144).

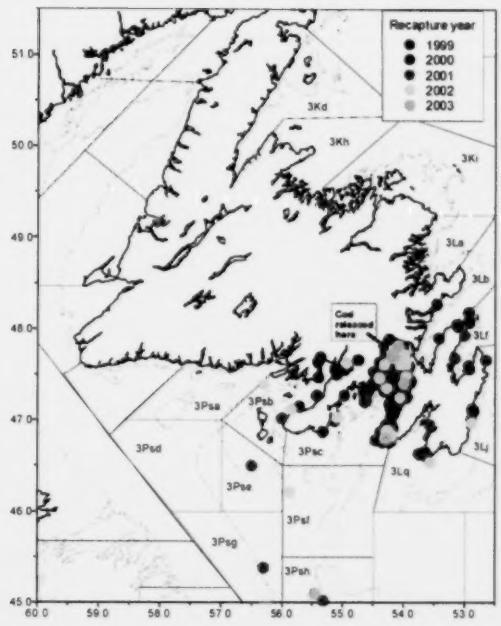
Fig. 3D. Recaptures of cod tagged in 3Psh during April 1998-2003.

Reported recapture positions (dots) for cod tagged and released in Halibut Channel during 11-18 April 2002 (N=1509).

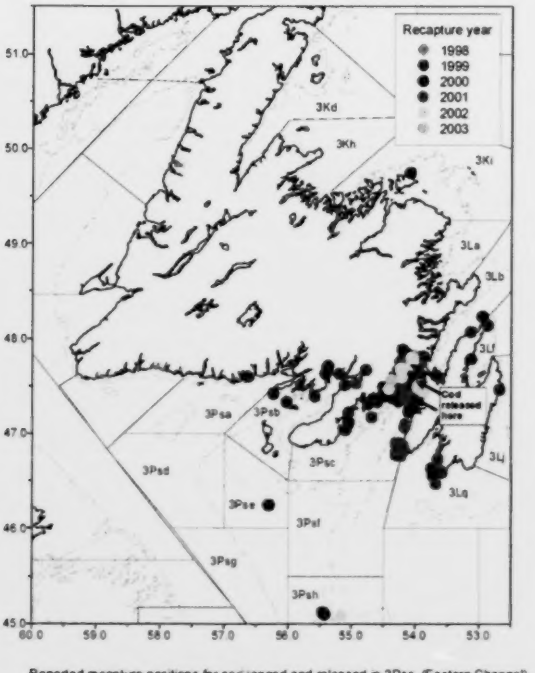
Fig. 3D. Recaptures of cod tagged in 3Psh during April 1998-2003.



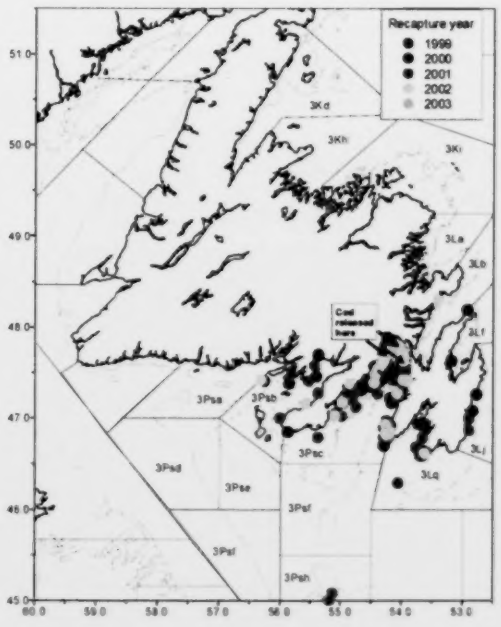
Reported recapture positions for cod tagged and released in 3Psc (Eastern Channel) during 19-24 October 1998 (N=511).



Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 29 April - 7 May 1999 (N=2494).

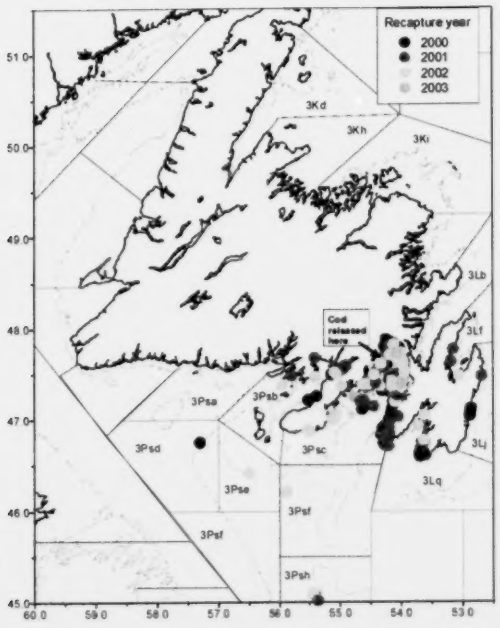


Reported recapture positions for cod tagged and released in 3Psc (Eastern Channel) during 17-22 October 1998 (N=883).

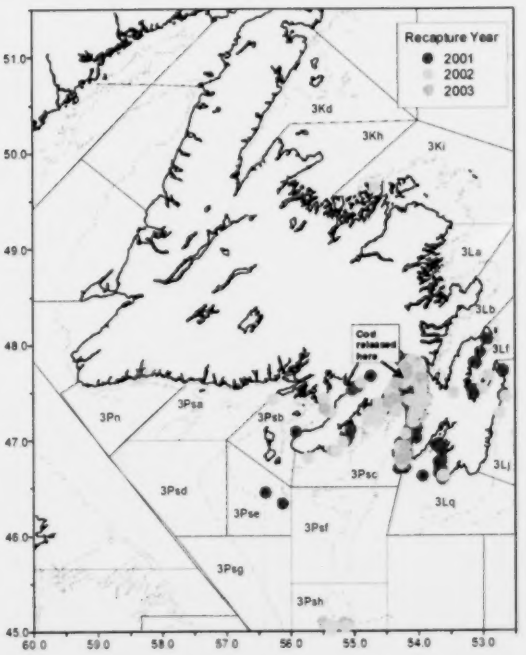


Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 8-17 Nov 1999 (N=2152).

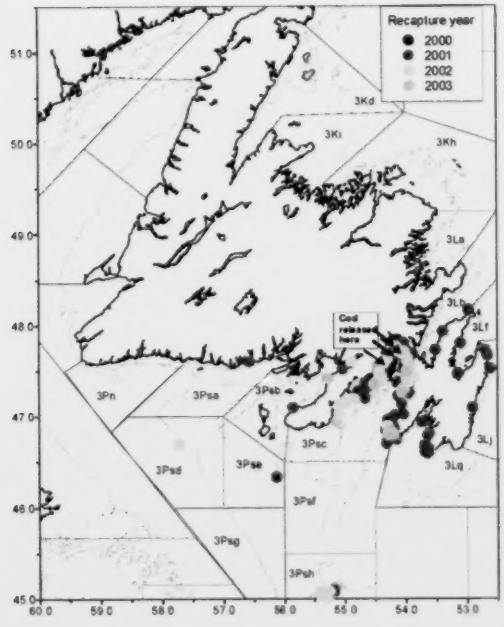
Fig. 3E. Recaptures of cod tagged in 3Psc during October 1998-May 2003.



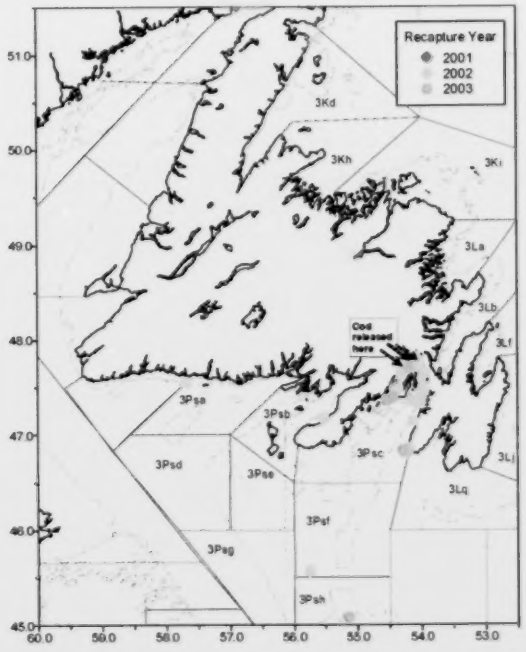
Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 26 April - 6 May 2000 (N=2494 and N=528).



Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 28 April - 7 May 2001 (N=1704 and N=2273).

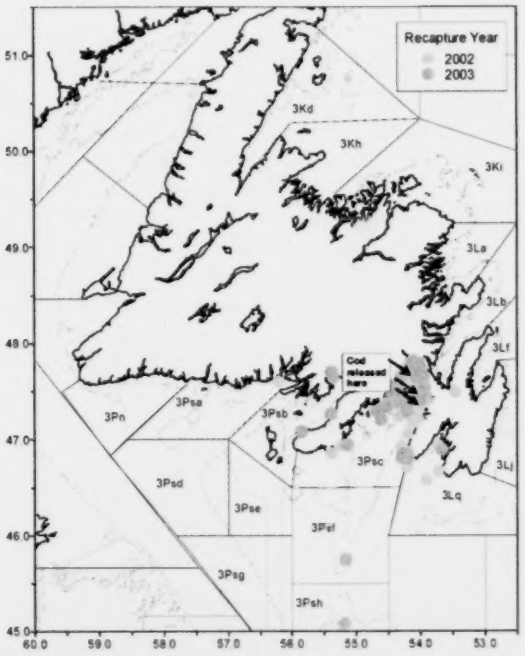


Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 5-15 Nov 2000 (N=1165, N=792 and N=1212).

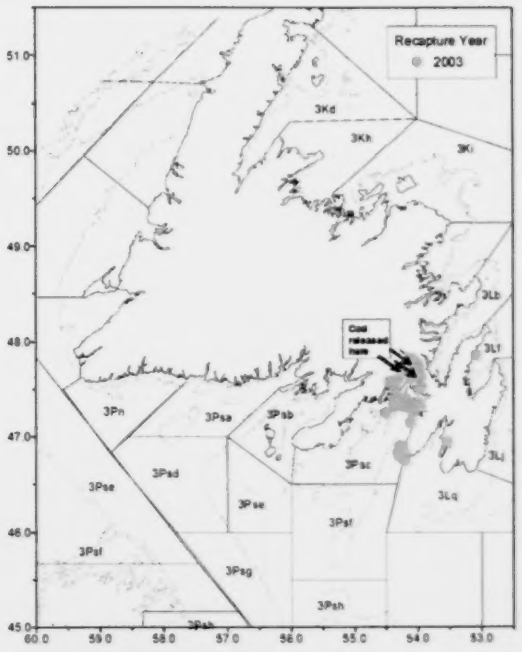


Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 22 Nov 2001 (N=350).

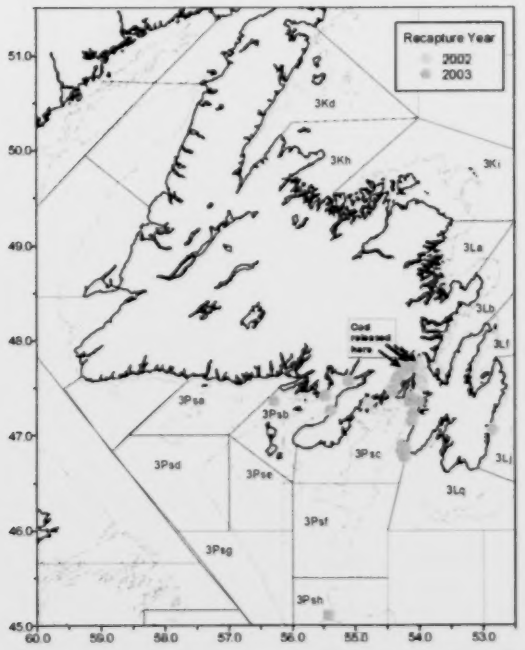
Fig. 3E. Recaptures of cod tagged in 3Psc during October 1998-May 2003.



Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 27 April - 7 May 2002 (N=1832 and N=1399).



Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 28 Apr.-11 May 2003 (N=3,427).



Reported recapture positions for cod tagged and released in 3Psc (inner Placentia Bay) during 12-18 Nov 2002 (N=1,676).

Fig. 3E. Recaptures of cod tagged in 3Psc during October 1998-May 2003.